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Impact of Drifting Buoy Observations on an NWP forecast - the case of 29th September 1995.

by

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March 1996

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Impact of Drifting Buoy Observations on an NWP forecast - the case of 29th September 1995.

J.R.Grant, R.J.Graham and M.J.Bader (Observation Evaluation Group)

Abstract

Differences between consecutive operational forecasts of the Local Area Model (LAM) of the UK Met Office indicated that observations between 0600 and 1200 on 28 September 1995 had a marked positive impact on the model evolution, in particular on an area of rain forecast to move close to the UK. This study sought to identify the data types that contributed most of the benefit.

The method involved running a series of 24-hour forecasts of the LAM, each assimilating different observation types. Forecasts were then compared, mainly using fields of MSL pressure, 850 hPa wet bulb potential temperature and 6-hour rainfall accumulations.

Most individual observation types did not improve the forecast significantly but surface observations had a large impact. In this case the major surface contribution came from drifting buoys, some of which were near a small depression in mid-Atlantic. The small-scale time resolution of the buoy data corrected the analysis in a sensitive region and produced significant differences in the evolution.

1. Background

The numerical forecasts from 27th and early on the 28th of September 1995, valid for 29/1200, incorrectly brought rain from the Atlantic across southern England. The forecast for the southern UK in the Global and the Local Area Model (LAM) runs was not corrected until 28/1200.

The aim of this study is to identify the observations that corrected the numerical forecast. There was little difference, over the British Isles, between the LAM runs at 28/0000 and 28/0600; the forecast was still in error. The major difference occurred between the 28/0600 and 28/1200 runs. The impact of observations input between these two times was investigated. The reasons for the error in the 28/0000 and 28/0600 runs are not addressed here.

2. Synoptic situation

A small depression, Low U (Fig. 1), drifted north from the subtropics. It was steered to the southwest of the UK in the flow on the forward side of an upper ridge (Fig. 2), downstream of developing Low A. The rain area associated with Low U (which later decayed into a trough) was therefore kept away from the UK.

However in the 28/0600 run Low U was initially too deep and too far north, Low A did not develop enough and the upper ridge was less pronounced. Therefore the remnants of Low U were steered on a more easterly track towards the UK. In the 28/1200 run the upper ridge and the evolution of Low U were closer to reality.

Between 28/0600 and 1200 CFO noticed that the initial analysis in mid-Atlantic was incorrect and used bogus data to try to move Low U a little to the south but this had little impact on the forecast. These bogus data were not used in our runs.

3. Model Experiments

The LAM was run to produce a 24-hour forecast from the 28/1200 analysis. There was a 6-hour assimilation cycle between 28/0600 and 1200 (see Fig. 3) during which various observation types were assimilated:

All observations (ALLOBS), corresponding to the operational run of 28/1200,
No observations (NOOBS), corresponding to the operational run of 28/0600,
Radio-sonde winds only,
Radio-sonde temperatures only,
Radio-sonde humidities only,
Aircraft winds only,
Aircraft temperatures only,
Surface observations only,
Satellite wind data only,
Satellite temperature data only.

The resulting forecasts were compared, mainly using fields of MSLP, 850 hPa wet bulb potential temperature (WBPT) and 6-hour rainfall accumulations although other fields were also available (such as vertical velocity and potential vorticity (PV)). After the results of these initial runs were evaluated, others were performed as necessary, to identify more precisely the key observations giving the most significant improvement to the forecast.

4. Results

4.1 Comparison between ALLOBS and NOOBS

4.1.1 MSLP

The ALLOBS and NOOBS runs produced the two extremes of the forecasts. Figs. 4-6 show the MSLP and differences at t+0 (28/1200), t+12 and t+24. At t+0 the observations have increased the MSLP by 4 hPa at 30°W just north of Low U (Fig. 4) and this difference amplified during the forecast as the low moved towards Ireland, increasing to 9 hPa at t+24 (Fig. 6).

It was significant that Low A, west of 30°W, had deepened more in the ALLOBS run. (Troughing to the east of the low can be seen at the top left of Fig. 6.) Warm advection ahead of Low A (seen in Fig. 2), enhanced the downstream upper ridge thus veering the upper flow on its eastern flank. Low U, which was situated in this region, was therefore steered further south into the SW Approaches instead of over Ireland (Fig. 2).

4.1.2 Rainfall

Figs. 7-8 show rainfall accumulations for two 6-hour periods. The ALLOBS run had less rainfall associated with Low U, the differences over Ireland reaching 8 mm (Fig. 8), where the rain area was just skirting SW Ireland. Later the rain area moved towards Brittany. This evolution, in the ALLOBS run was much closer to what happened (Fig. 9), although the radar display showed that the actual rain was closer to Brittany, having been advected more quickly towards the southeast. The rainfall in the trough from Low A off SW Iceland was greater in the ALLOBS run but there are no data to verify which run is more accurate in this region.

4.1.3 850 hPa WBPT

Figs. 10-12 show the 850 hPa WBPTs. At t+0 (Fig. 10) there was more sign of circulation near Low U in the NOOBS analysis, due to the deeper low. This circulation increased the WBPT just north of the low by up to 2°C compared to the ALLOBS run. Again the difference amplified during the forecast and the NOOBS run had the higher WBPTs into SW Ireland at t+24 whereas the good run (ALLOBS) had them further to the southwest.

4.2 Comparison between NOOBS and individual data types

Most of the runs using individual observation types did not improve the NOOBS forecast significantly. This result implies that in most cases, where there were observations, the values in the model background and the observations were similar. The run with surface observations gave the most beneficial impact, followed by that with aircraft winds. These runs are discussed below.

4.2.1 Aircraft winds only

Figs. 13-14 show a very slight improvement in the forecast compared to the NOOBS run at t+24 in that the trough extending to Ireland was less deep when the observations were included and there were slight differences in the rainfall. The evolution of Low A was very similar in both runs.

4.2.2 Surface observations only - all data

The run using surface observations only (Figs. 15-17), showed significant improvements to the MSLP and the rainfall over Ireland, compared to the NOOBS run. This run held back the trough, and rain was only forecast for the extreme southwest of Ireland. Comparison with the ALLOBS run (Fig. 8) showed that most of the impact from all observations had been caught in this run. The observations had improved the analysis by increasing the central pressure of Low U and moved it south by 1 degree. Even then, Low U was still about 1 degree north of CFO's manually analysed position. This run also slightly deepened Low A at T+24 to be more in line with reality.

The main improvements originated (see Fig. 15) near Low U. There were several drifting buoys and a few ships in the area (Fig. 18) and the impact of these observations was investigated.

4.2.3 Drifting buoy data only

A run using drifting buoy data only (Figs. 19-21) disclosed that the main impact was from buoy data rather than ship data, both for Low A and Low U (compare Figs. 18 and 20). The central pressure of Low U at t+0 was raised (Fig. 19). At t+24 the trough near southwest Ireland had again been held back relative to the NOOBS run (Fig. 20). Although still touching the southwest of Ireland, the rain area (Fig. 21) was as good as that in the run with the full surface data (Fig. 17).

Another run (not shown) of surface data only but minus the drifting buoys confirmed that the faults of the NOOBS run were still present. A further run using ALLOBS minus drifting buoys still produced too large a rain area over Ireland with rainfall totals too high (Fig. 22). It was therefore deduced that the observations from drifting buoys had significantly improved the forecast.

The differences between MSLP data from two drifting buoys near Low U, the model background and analysis values are shown below:

	DB 44769			DB 44613		
Date/time	53.9N 31.4W			51.8N 28.8W		
	Ob	Ob-bkgd	Ob-anal	Ob	Ob-bkgd	Ob-anal
28/0600	1017.4	4.3	2.5	1013.8	1.2	0.8
28/0900	1015.2	4.1	1.5	1011.0	0.3	-0.8
28/1200	1013.2	2.5	3.4	1009.2	-2.0	-0.5

The reasons why the drifting buoy data were so effective in this case were:

(a) the model background MSLP was in error near Low U;

(b) there were two drifting buoys near Low U;

(c) because drifting buoys report continuously (the UK assimilation scheme filters these observations down to one per hour or less), they have more impact than ship observations which may only be received once every 6 hours.

In the course of the investigation it was found that observations from moored buoys were assimilated once every three hours, although they were available every hour.

5 Impact of surface data on the upper air

It is instructive to see how the assimilation of surface data influenced the upper air. Examining the PV on the 300K surface (chosen because this surface was in the middle troposphere, around 600 hPa near Low U) for the NOOBS and ALLOBS runs (Figs.23-24), there was a difference around 54N 30W even at t+0 which increased during the forecast. When surface data only were used (Figs. 25-26) there was a similar, although slightly smaller, difference. Thus the impact spread from the surface up to 600 hPa even within the assimilation period of 6 hours. The run using drifting buoy data only (Figs. 27-28) captured most of the impact from the surface data, both at t+0 and at t+24. Note the similarity of Figs. 24 and 28 showing that the observations from drifting buoys contributed a large part of the impact. At the level of the 300K surface the impact of aircraft winds was small (Fig. 29).

6. Conclusion

A significant improvement to the 24-hour forecast came from observations recorded by drifting buoys in the Atlantic. These data raised the MSLP analysed near a small depression, weakening the low-level circulation and also influencing the middle troposphere. Evidently the buoys were situated in a particularly sensitive region where small differences in the low-level analysis produced significant differences in the evolution. Thus more observations in sensitive areas could be very useful, as any error in these areas is likely to grow as the forecast proceeds. One aim of the forthcoming Fronts and Atlantic Storm Tracks Experiment (FASTEX), which will cover the same area of the Atlantic, is to investigate the use of observations in sensitive areas.

7. Recommendations and future improvements

The main issue here is: Can anything be done to reduce the frequency of future errors such as this one? In this case, surface data in the key area were more important than upper air reports. The aim should be to improve the model's analysis by maximising the use of existing data and incorporating new data especially from satellites.

Some recommendations that might improve the initial analysis:

(i) Existing automatic data, particularly from moored buoys, should be assimilated when they are available.

(ii) Scatterometer winds should be used in the LAM to capture smaller scale systems; however the swaths are quite narrow, so will not capture small systems very often.

(iii) More surface observations, eg drifting buoys, would be valuable in the North Atlantic, especially if they are between scatterometer paths.

(iv) The effects of analysis uncertainty could be identified using ensemble forecasts or sensitivity studies. This technique would identify areas that needed particular care in the analysis.

In the longer term, the frequency of analysis errors, similar to the one discussed, is expected to be reduced, for example, by:

(i) Future satellite observations with finer resolution to give better analyses (e.g. SSM/I data for surface winds and water content).

(ii) Improvements in the quality of current satellite sounding observations (e.g. locally produced soundings - GLOSS).

(iii) Sampling sensitive areas with Unmanned Airborne Vehicles. (This aspect is to be examined in FASTEX).

(iv) 4D Variational analysis.

(v) Increased vertical resolution in models.

Figures

1. MSL analyses at 1200 UTC for (a) 26 September, (b) 27 September, (c) 28 September and (d) 29 September 1995 showing the CFO hand-analysed positions of Lows U and A.

2. Model analyses at 1200 UTC for (a) 26 September, (b) 27 September, (c) 28 September and (d) 29 September 1995 at 500 hPa with 1000 to 500 hPa thickness (dashed lines). The CFO hand-analysed positions of Lows U and A are indicated.

3. Method: 6-hr assimilation and forecast.

4. MSLP at t+0:
   ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).
   The CFO hand-analysed position of Low U is indicated.

5. MSLP at t+12: ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

6. MSLP at t+24: ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

7. 6-hr rain accumulation 28/1200-1800:
   ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

8. 6-hr rain accumulation 29/0600-1200:
   ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

9. UK Radar 29/0930. The rain area is just seen in the extreme southwest.

10. 850 hPa WBPT at t+0:
    ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

11. 850 hPa WBPT at t+12:
    ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

12. 850 hPa WBPT at t+24:
    ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

13. MSLP t+24:
NOOBS, AC Winds only and the difference (NOOBS-AC winds only).

14. 6-hr rain accumulation 29/0600-1200:
NOOBS, AC Winds only and the difference (NOOBS-AC winds only).

15. MSLP at t+0:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs) only.
X marks the CFO hand-analysed position of Low U.

16. MSLP at t+24:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

17. 6-hr rain accumulation 29/0600-1200:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

18. Location of observations 28/1200 from ships (S), drifting buoys (DB) and a weather ship (OWS). X marks the CFO hand-analysed position of Low U.

19. MSLP at t+0:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

20. MSLP at t+24:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

21. 6-hr rain accumulation 29/0600-1200:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

22. 6-hr rain accumulation 29/0600-1200;
NOOBS, (ALLOBS - Drifting Buoys) and the difference.

23. PV on 300K surface at t+0:
NOOBS, ALLOBS and the difference (NOOBS-ALLOBS). X marks Low U.

24. PV on 300K surface at t+24:
NOOBS, ALLOBS and the difference (NOOBS-ALLOBS).

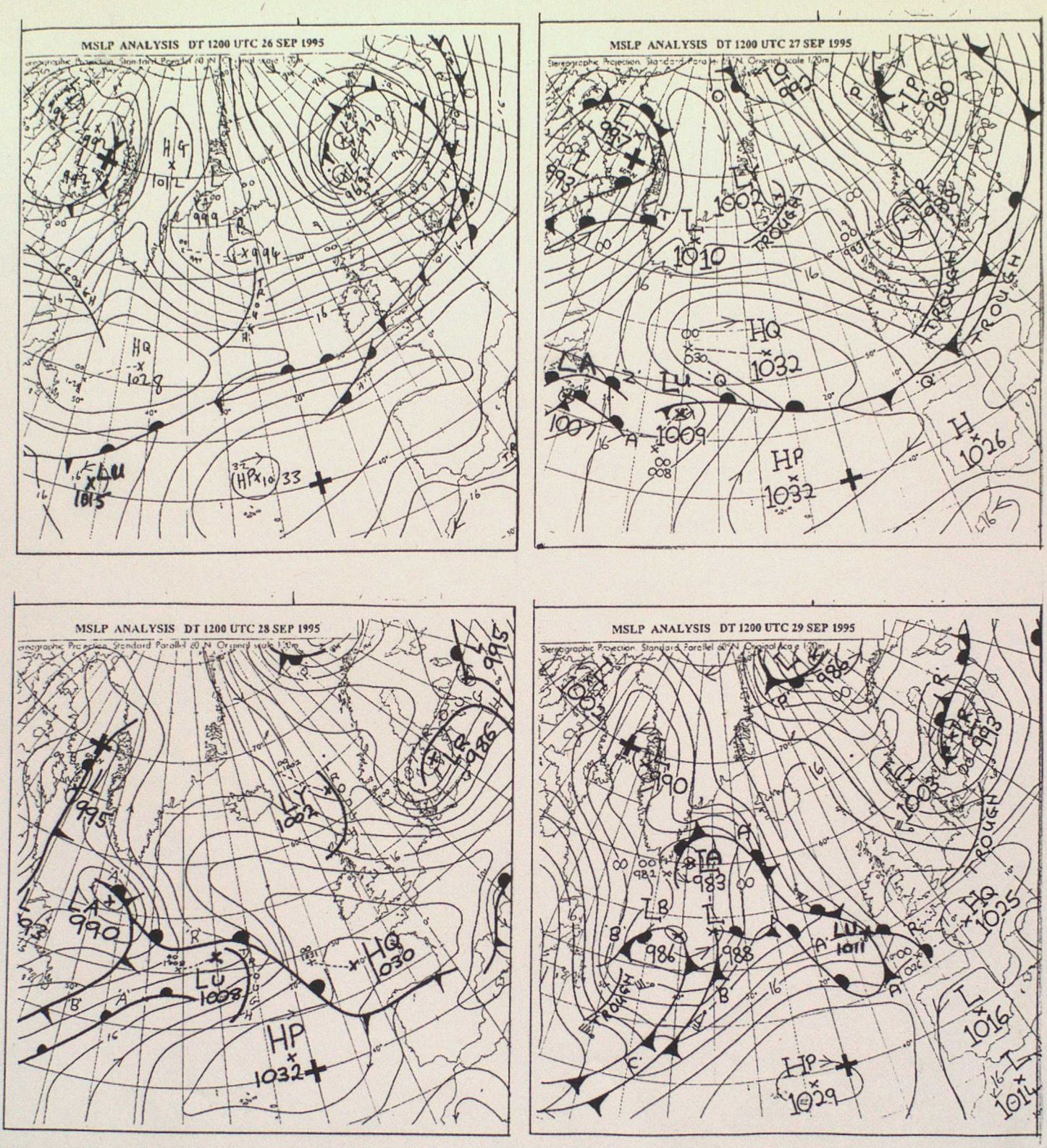
25. PV on 300K surface at t+0:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

26. PV on 300K surface at t+24:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

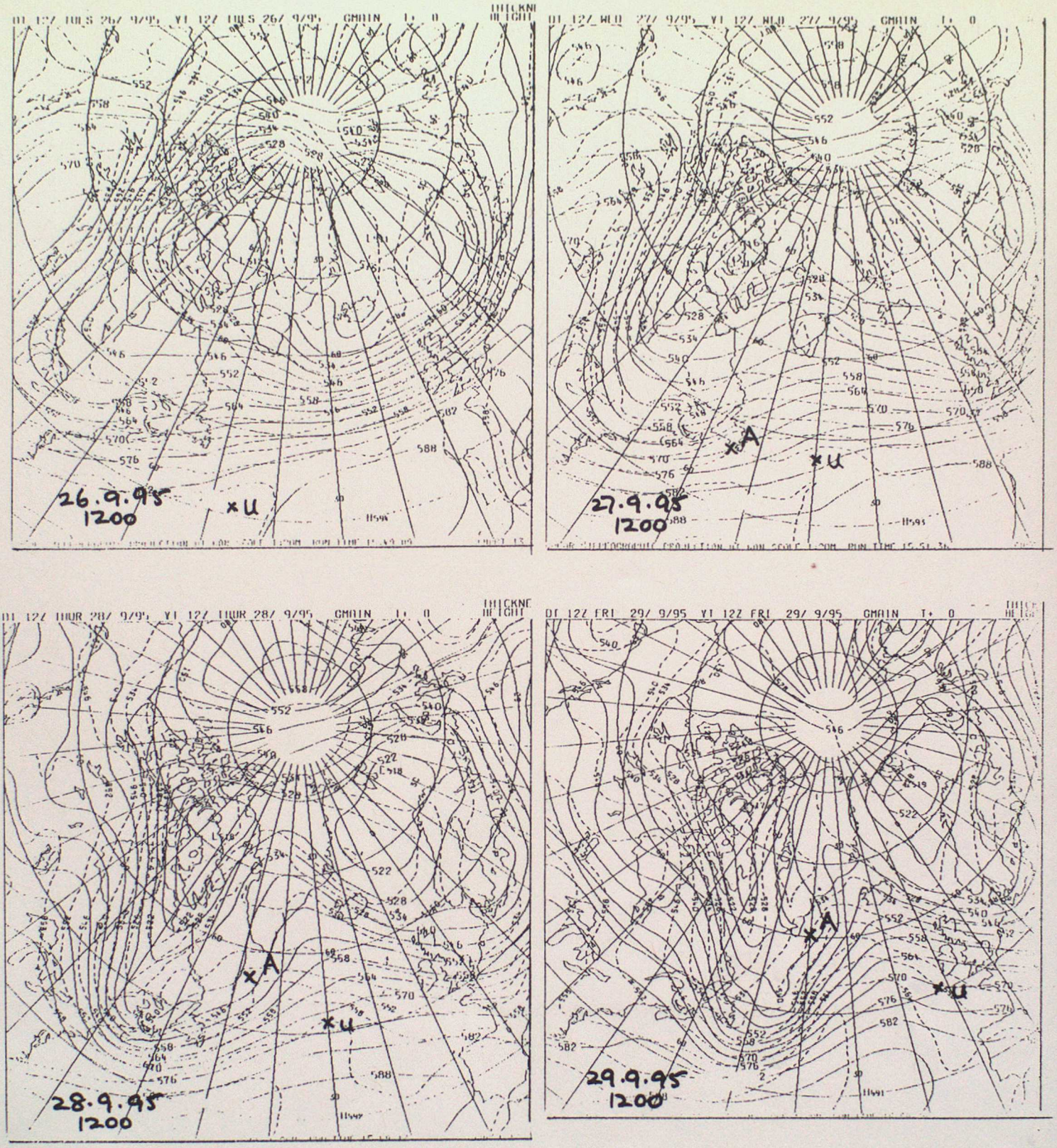
27. PV on 300K surface at t+0:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

28. PV on 300K surface at t+24:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

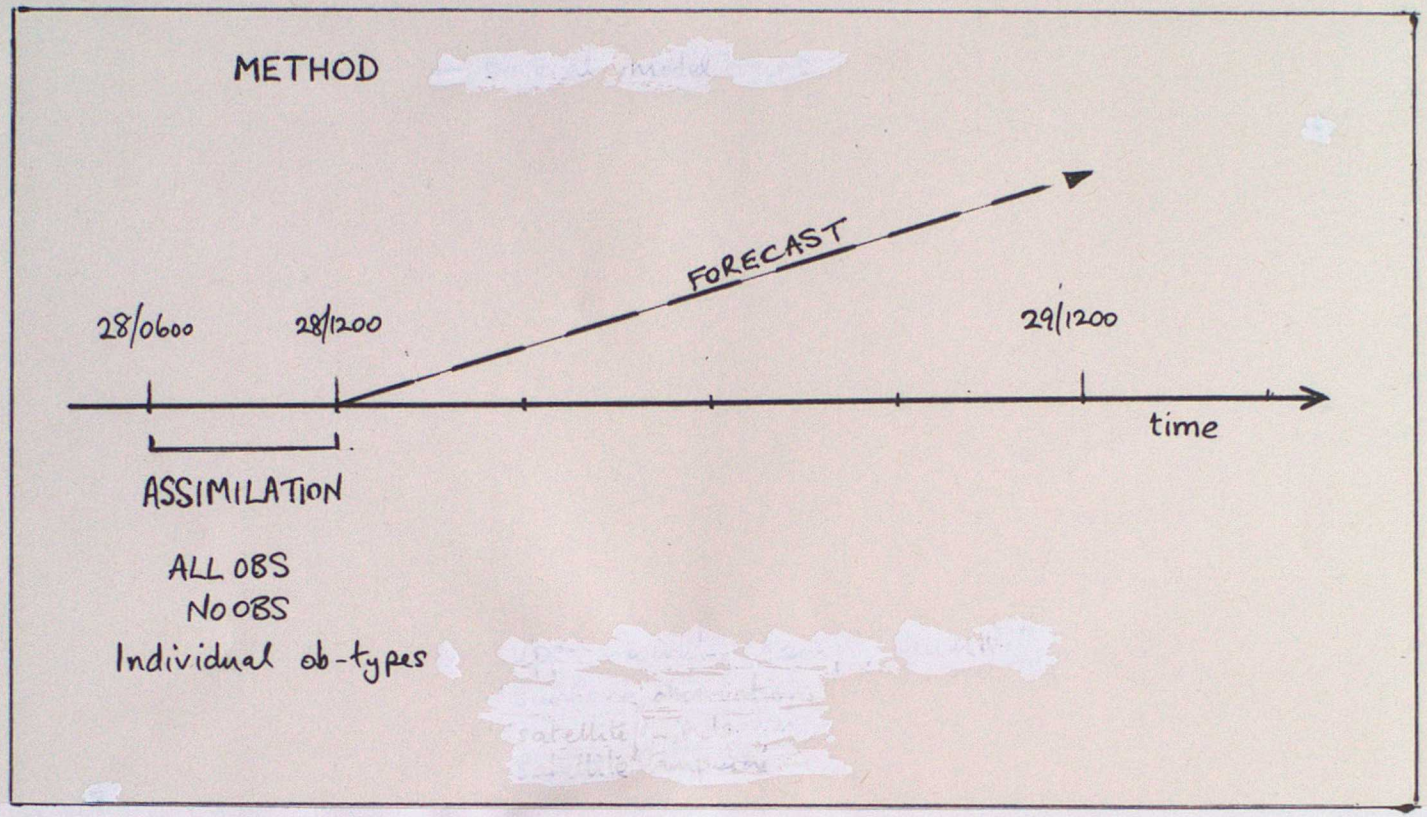
29. PV on 300K surface at t+24:
NOOBS, AC Winds only and the difference (NOOBS- AC Winds only).



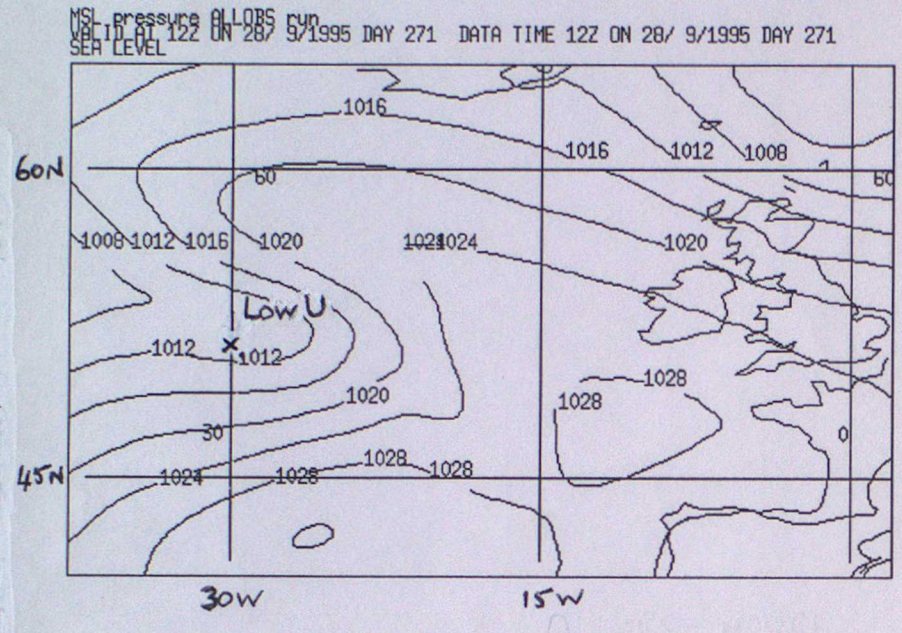
1. MSL analyses at 1200 UTC for (a) 26 September, (b) 27 September, (c) 28 September and (d) 29 September 1995 showing the CFO hand-analysed positions of Lows U and A.

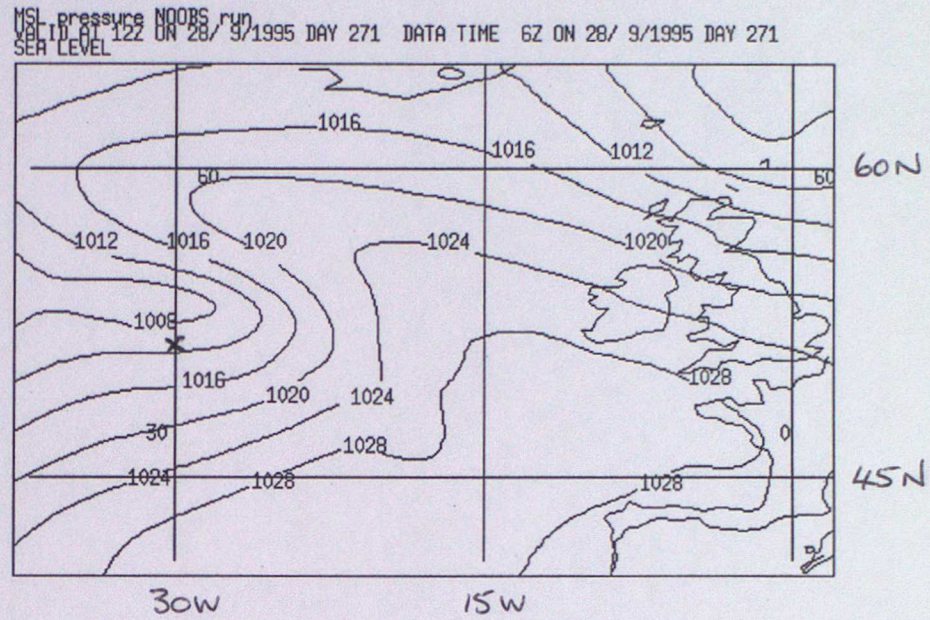


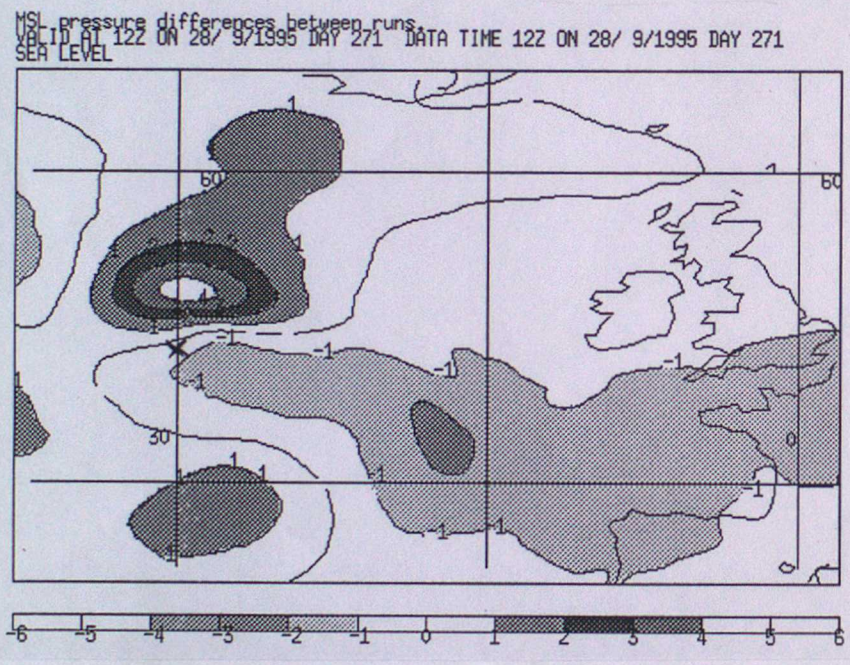
2. Model analyses at 1200 UTC for (a) 26 September, (b) 27 September, (c) 28 September and (d) 29 September 1995 at 500 hPa with 1000 to 500 hPa thickness (dashed lines). The CFO hand-analysed positions of Lows U and A are indicated.



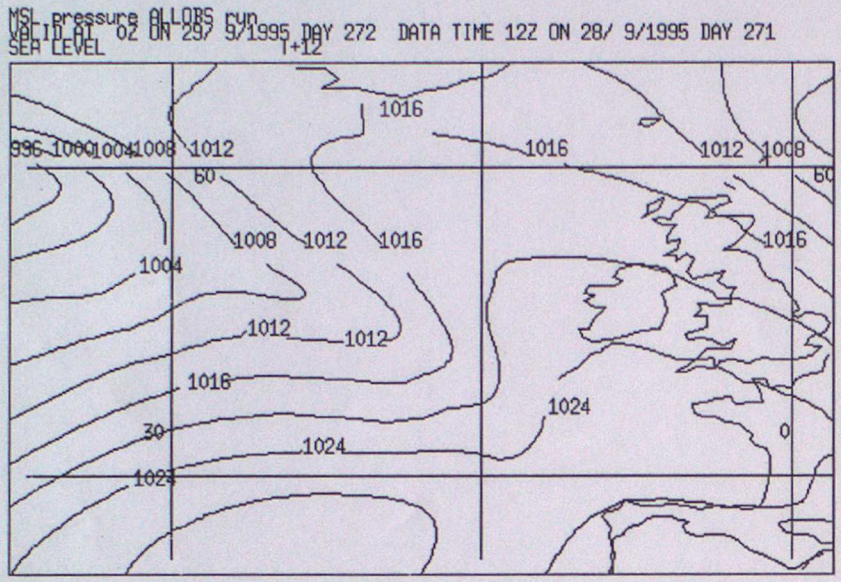
3. Method: 6-hr assimilation and forecast.

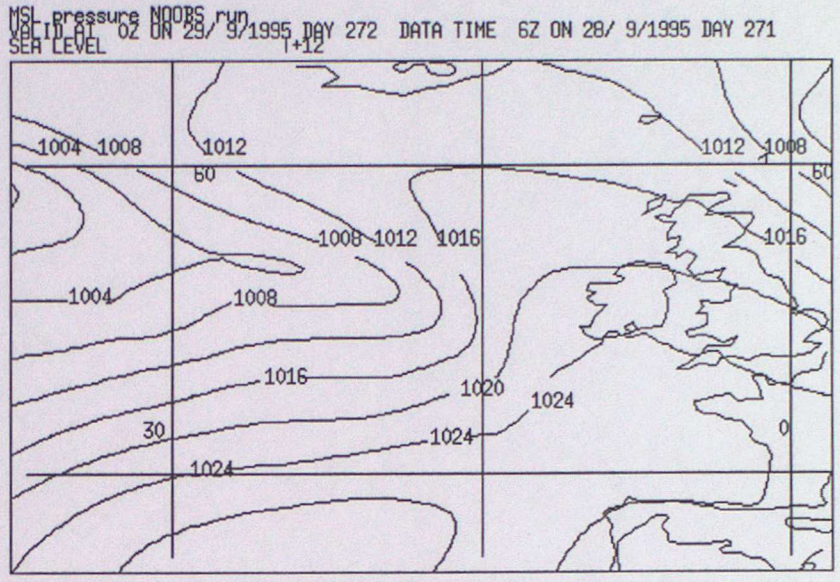


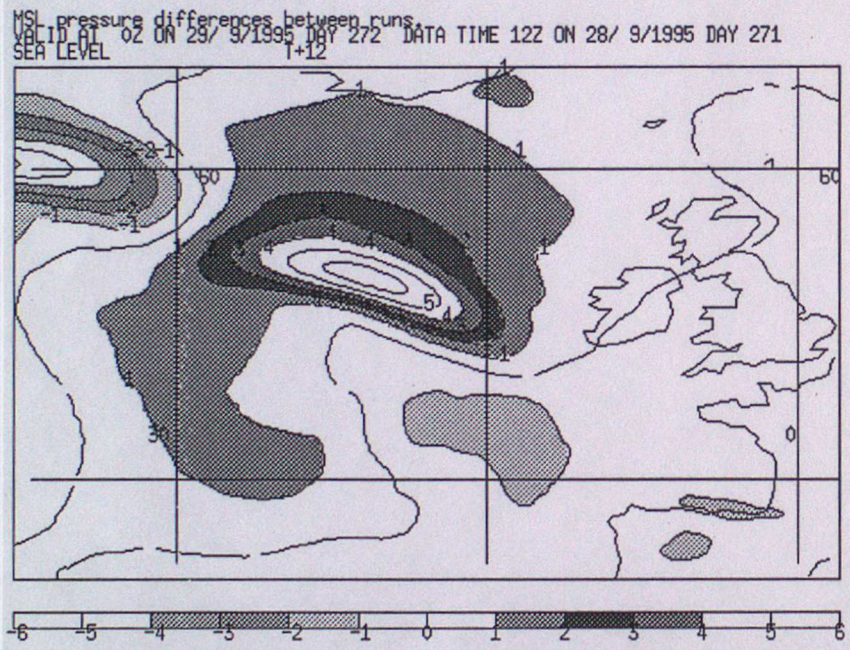




4. MSLP at t+0: ALLOBS, NOOBS and the difference (ALLOBS-NOOBS). The CFO hand-analysed position of Low U is indicated.

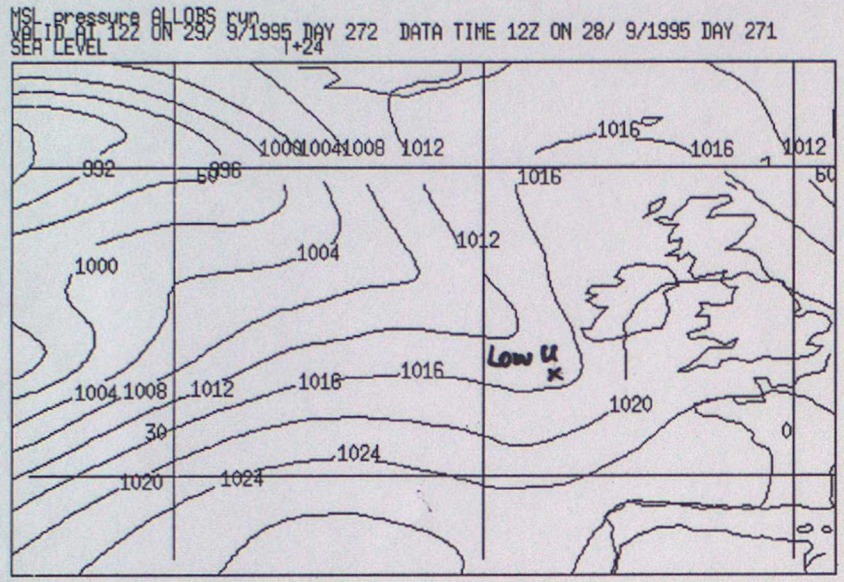


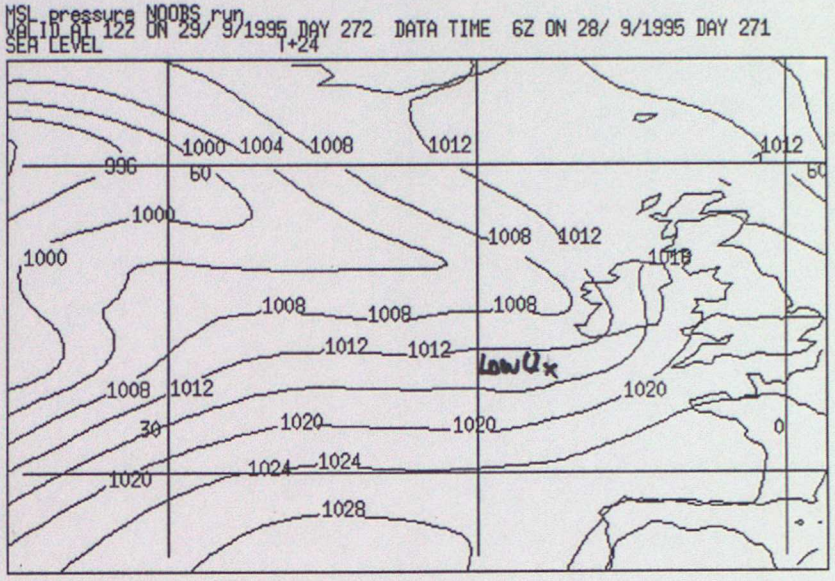


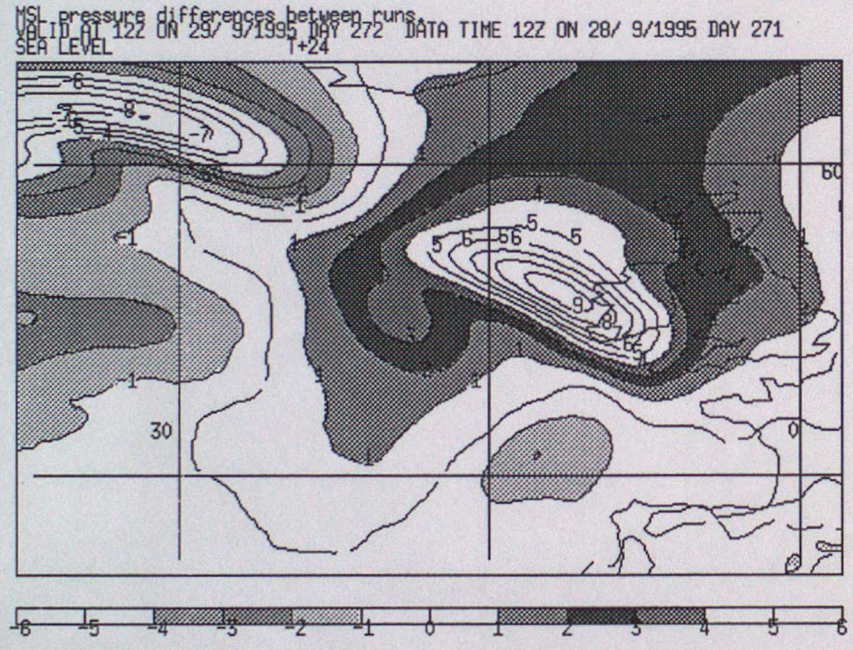


5. MSLP at t+12: ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

Screen dumped by Roger Grant at 10:57 on Tue 07 Nov 1995







6. MSLP at t+24: ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

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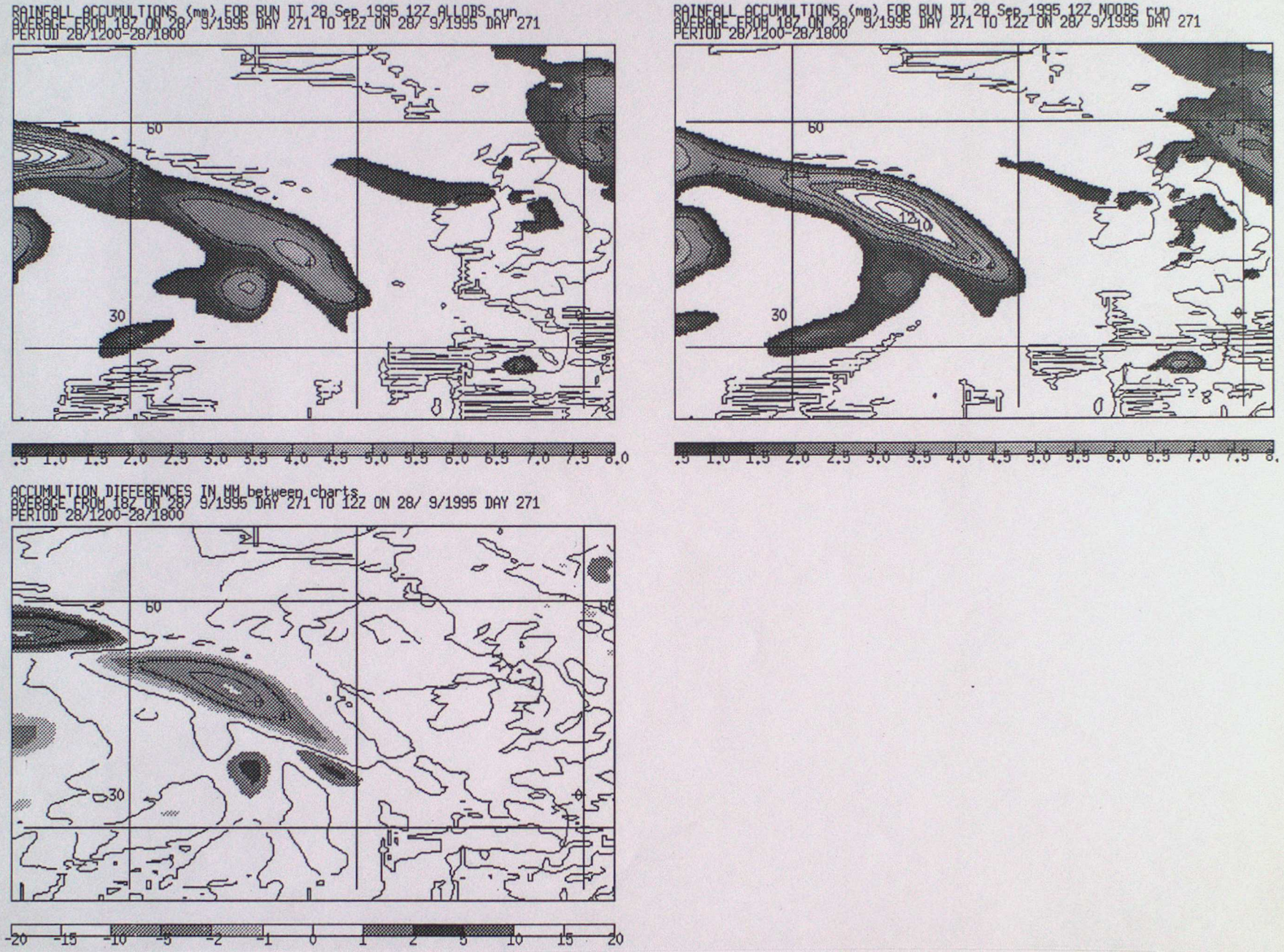
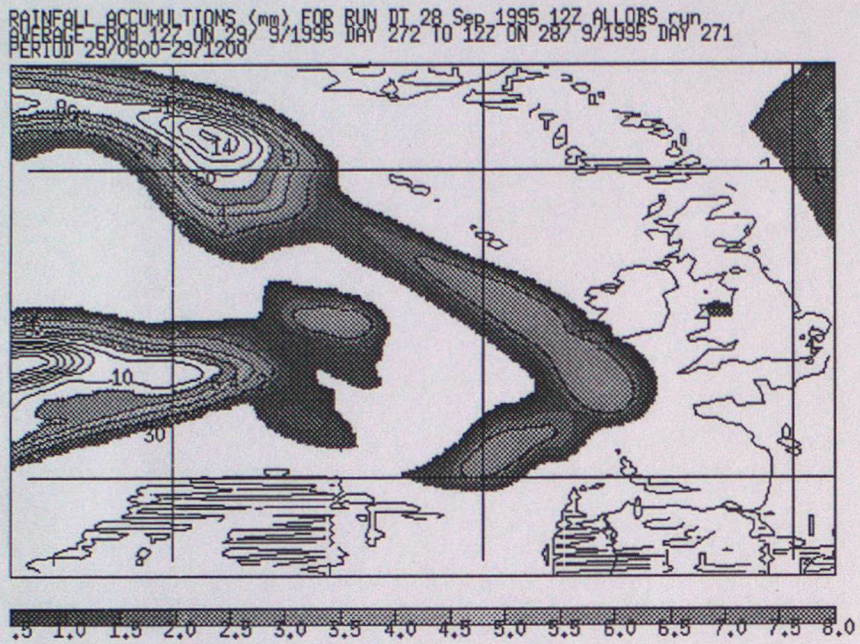
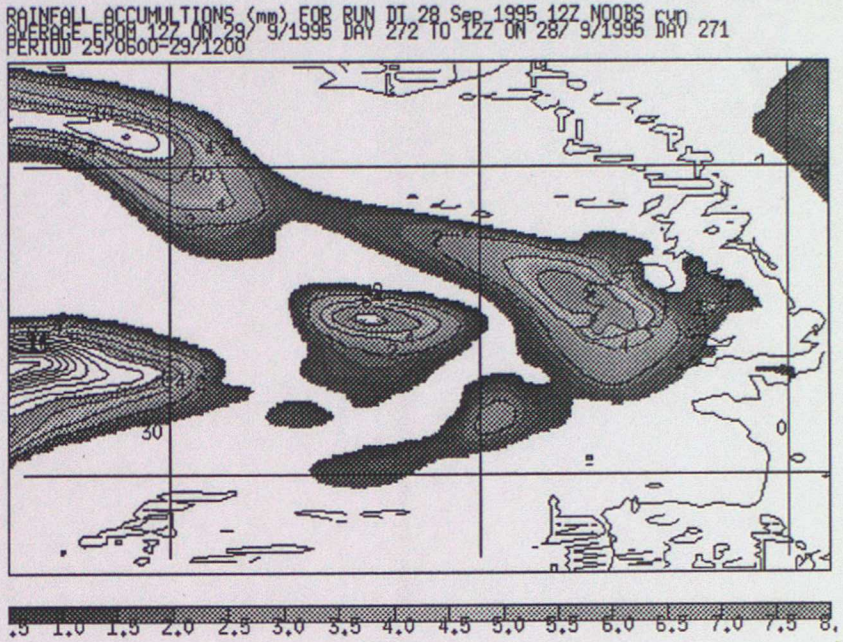
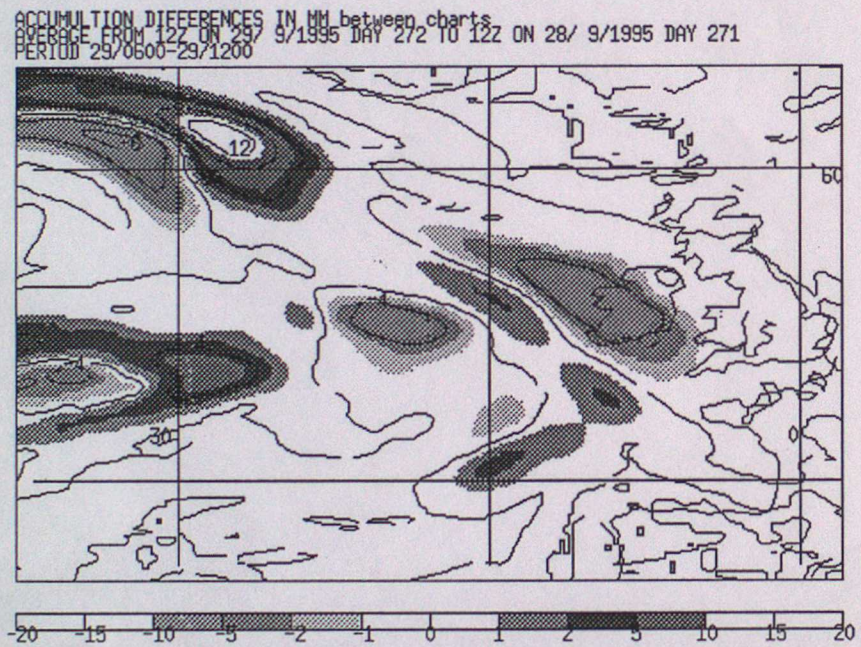


7. 6-hr rain accumulation 28/1200-1800:
ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

Screen dumped by Roger Grant at 11:39 on Tue 07 Nov 1995.

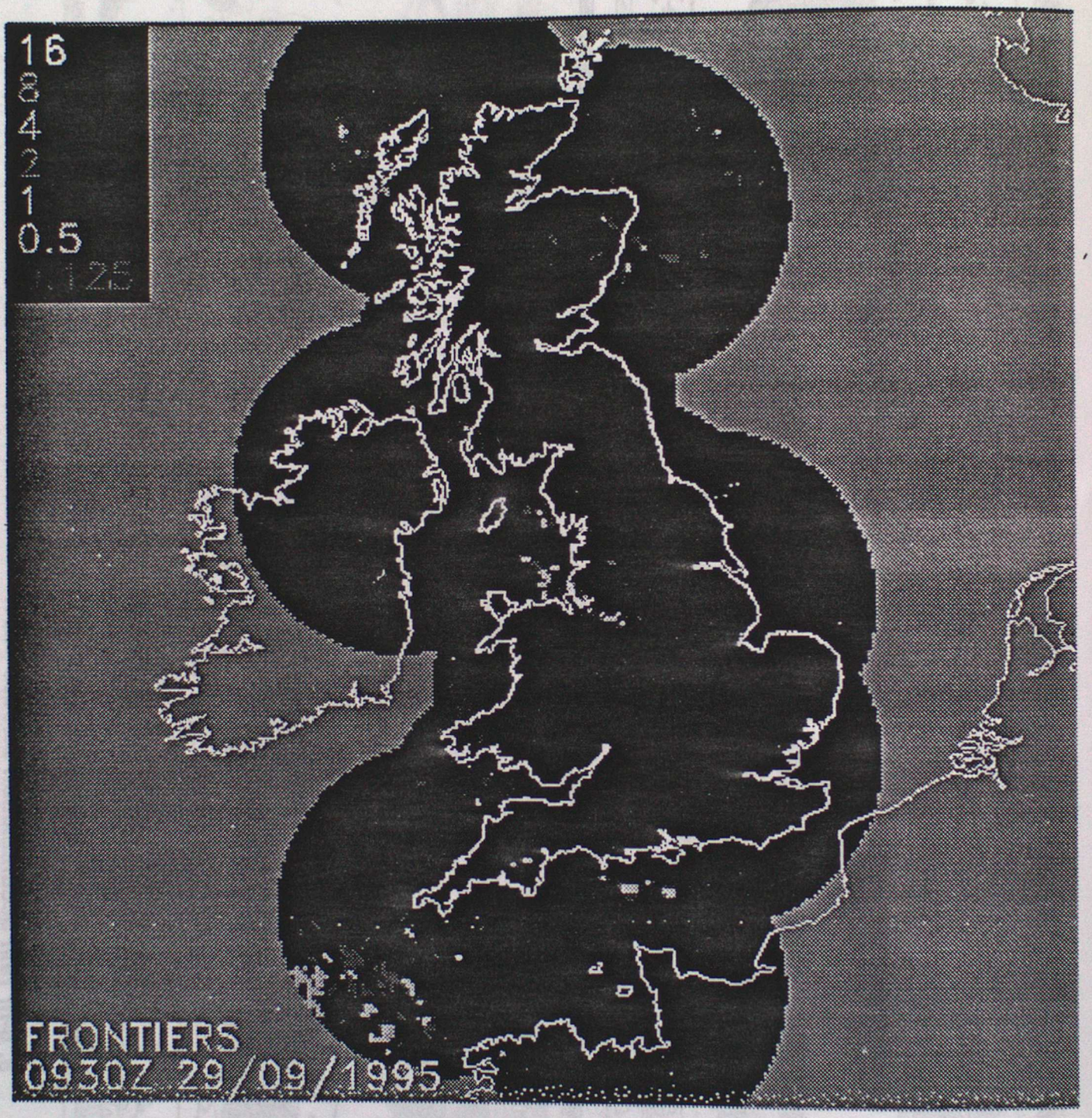




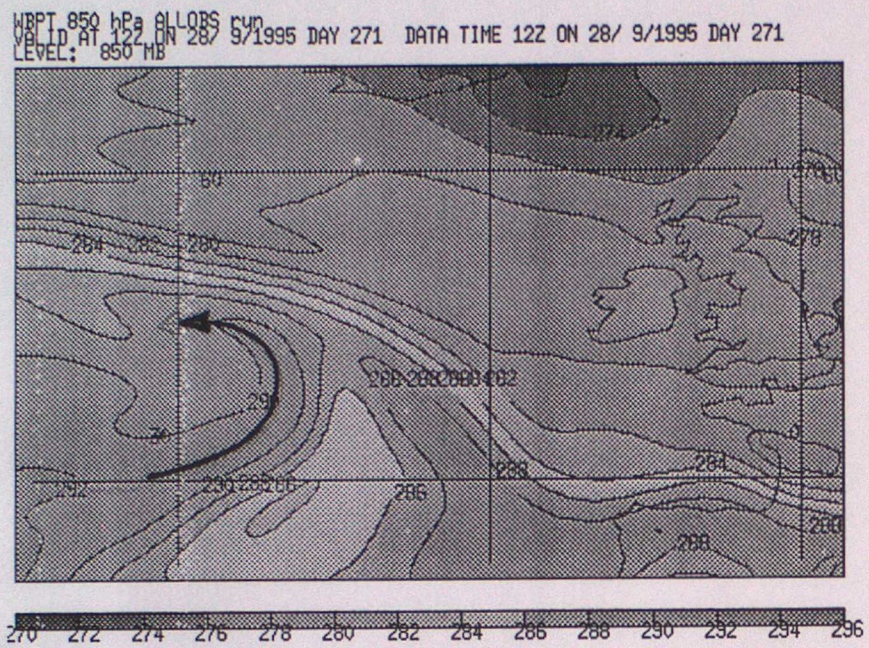


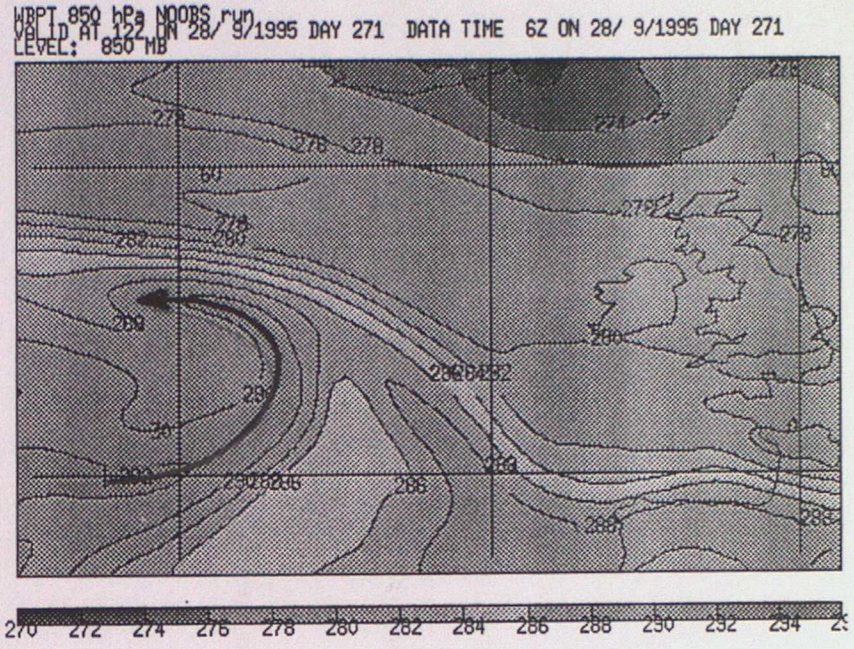
8. 6-hr rain accumulation 29/0600-1200:
ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

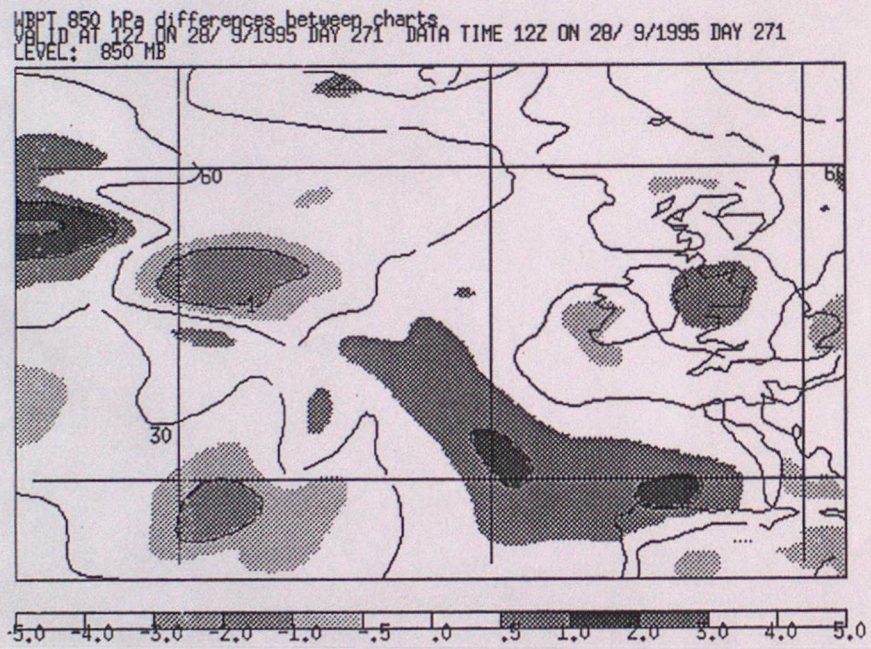
Screen dumped by Roger Grant at 11:33 on Tue 07 Nov 1995.



9. UK Radar 29/0930. The rain area is just seen in the extreme southwest.







10. 850 hPa WBPT at t+0:
ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

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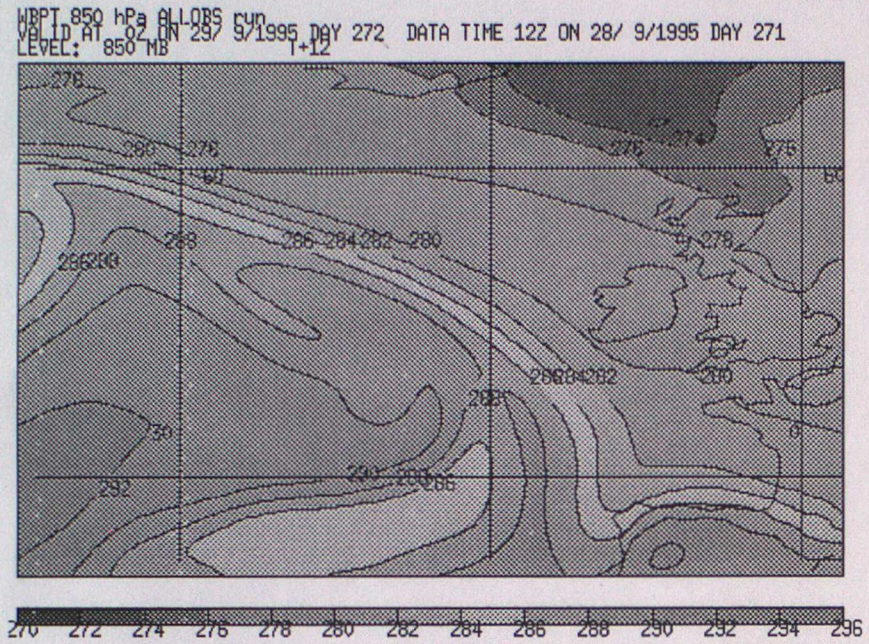
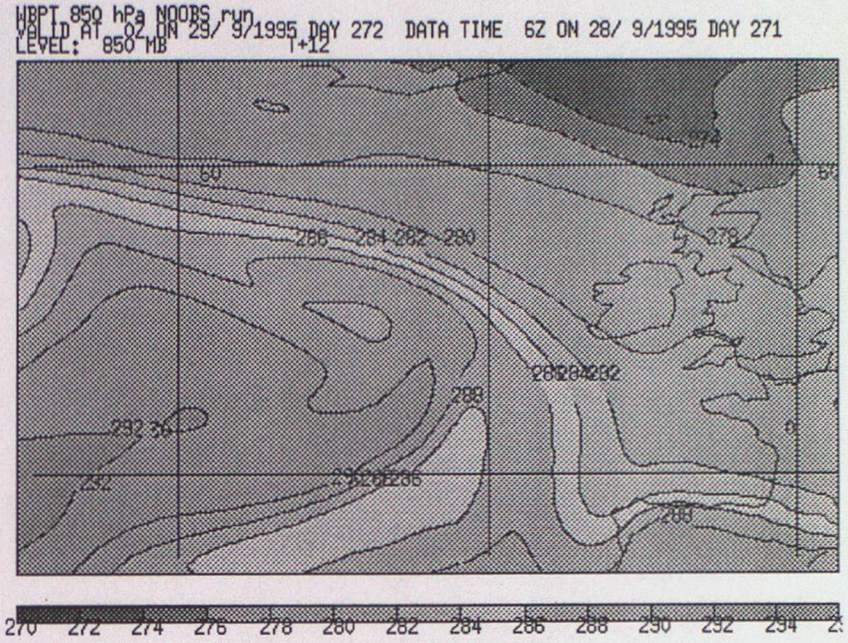
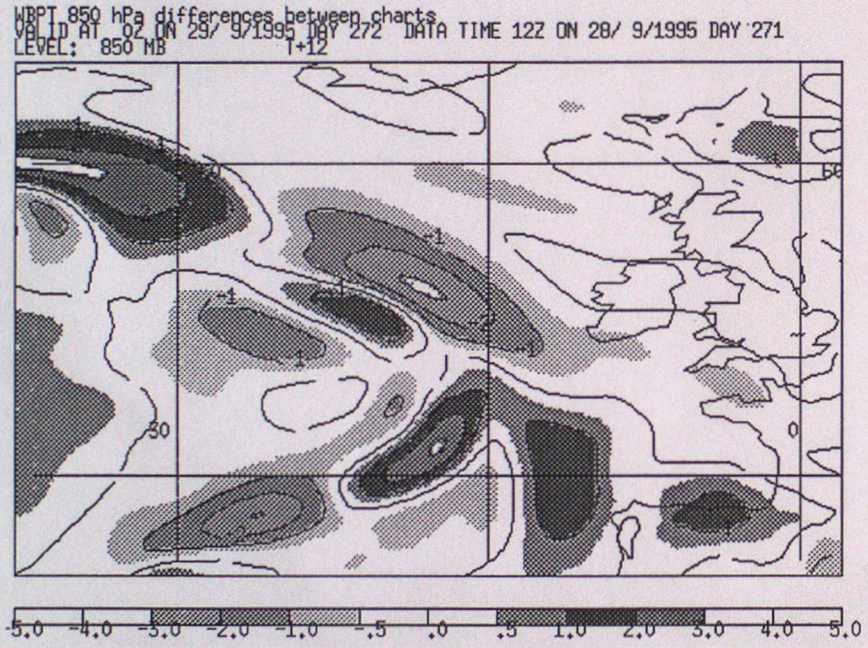
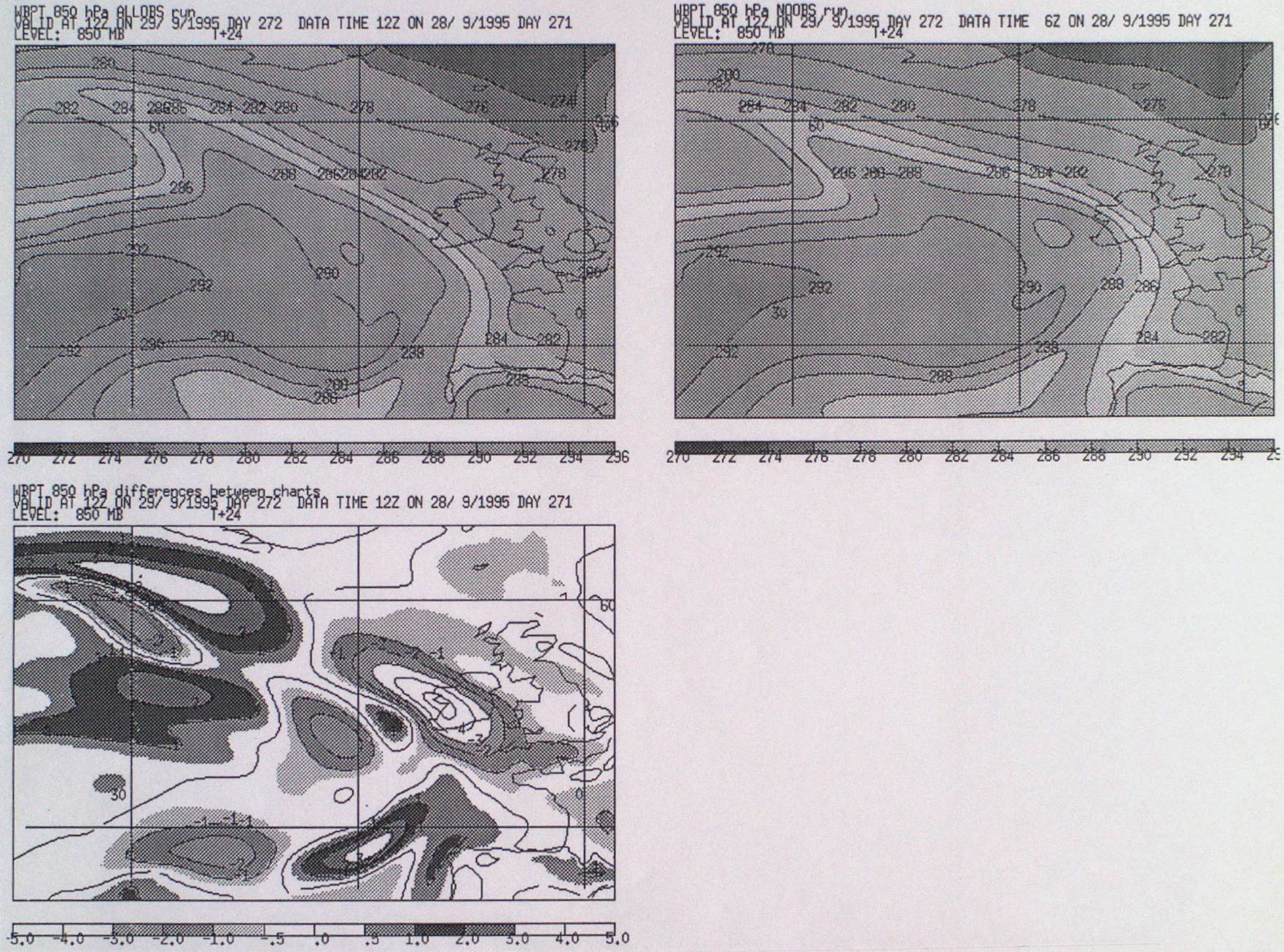






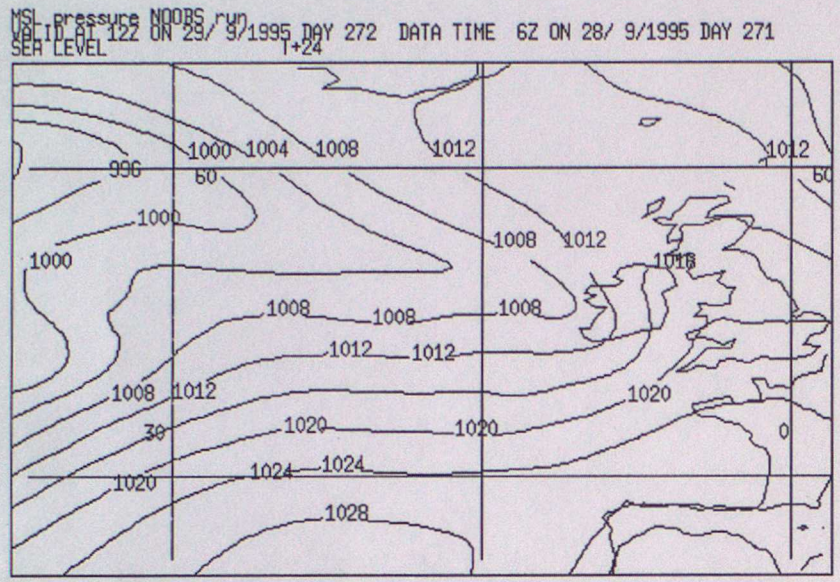
11. 850 hPa WBPT at t+12:
ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

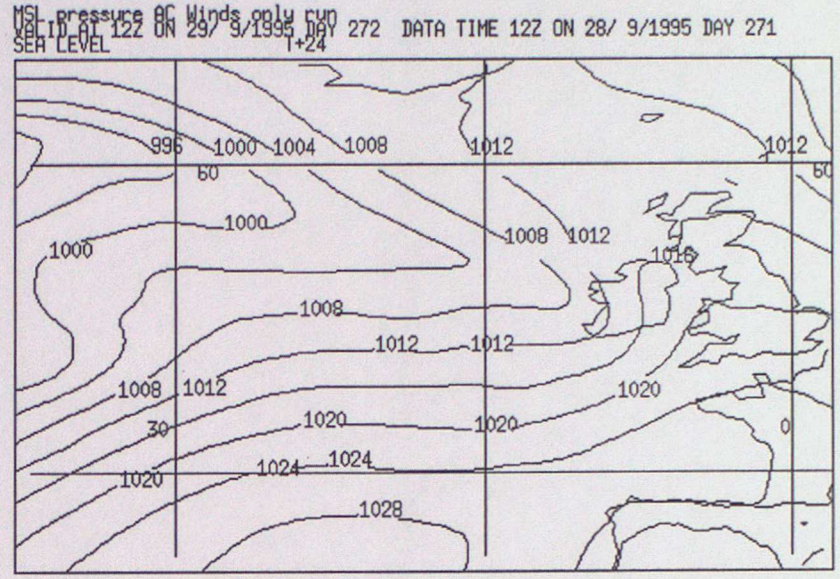
Screen dumped by Roger Grant at 11:23 on Tue 07 Nov 1995

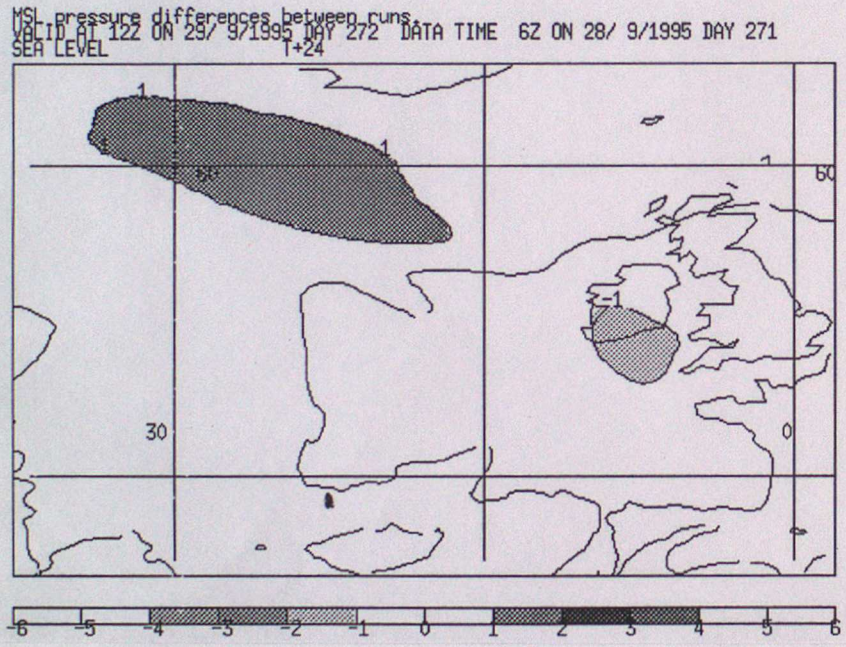


12. 850 hPa WBPT at t+24:
ALLOBS, NOOBS and the difference (ALLOBS-NOOBS).

Screen dumped by Roger Grant at 11:24 on Tue 07 Nov 1995



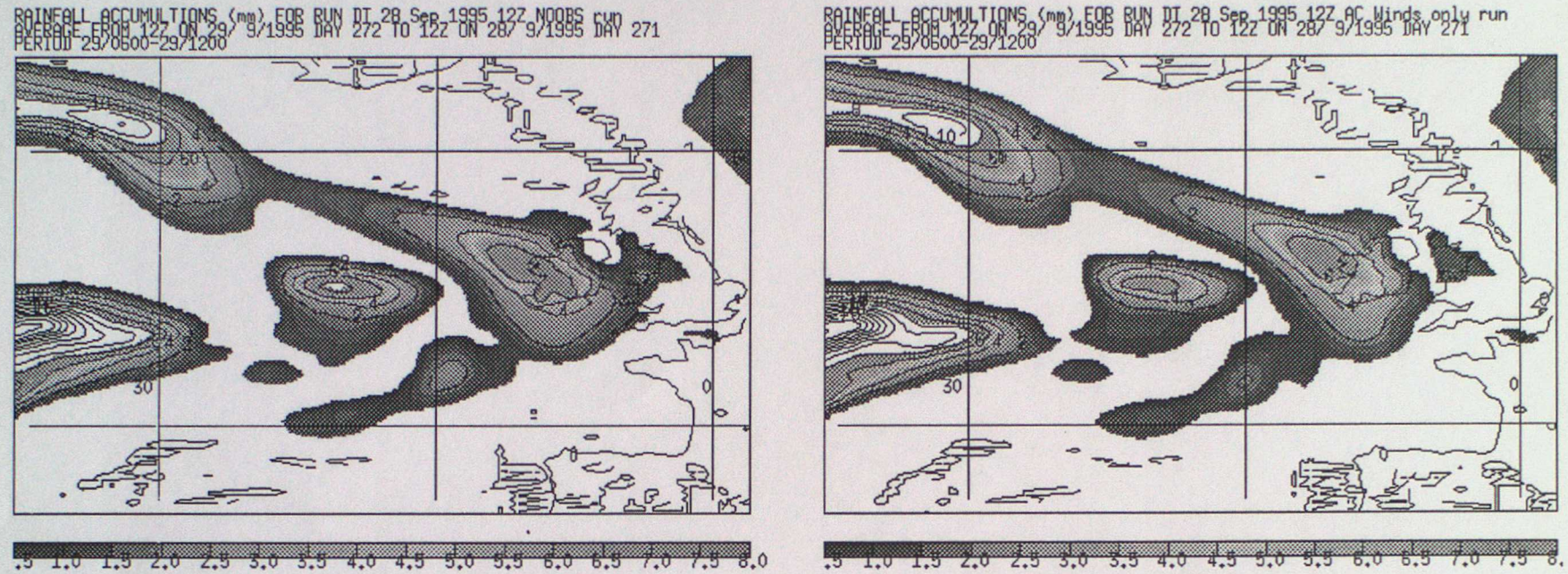




13. MSLP t+24:

NOOBS, AC Winds only and the difference (NOOBS-AC winds only).

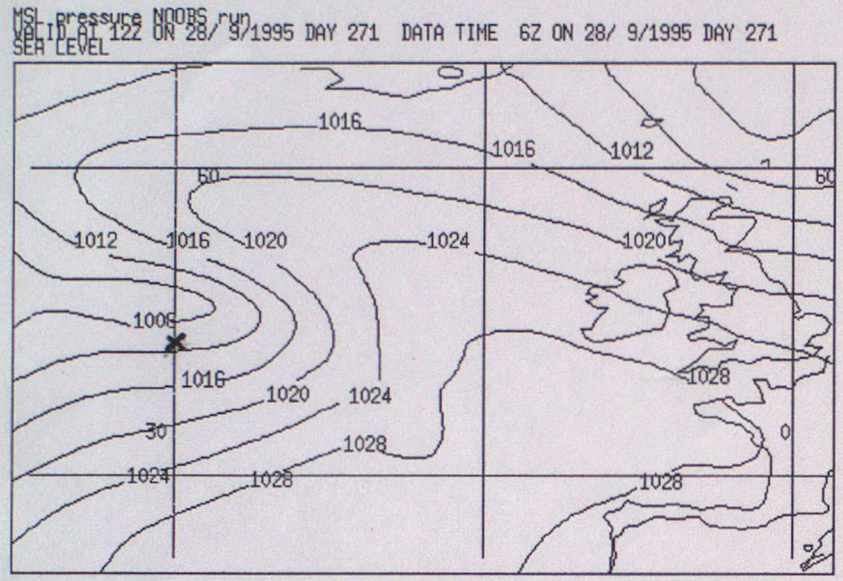
Screen dumped by Roger Grant at 15:37 on Fri 10 Nov 1995.

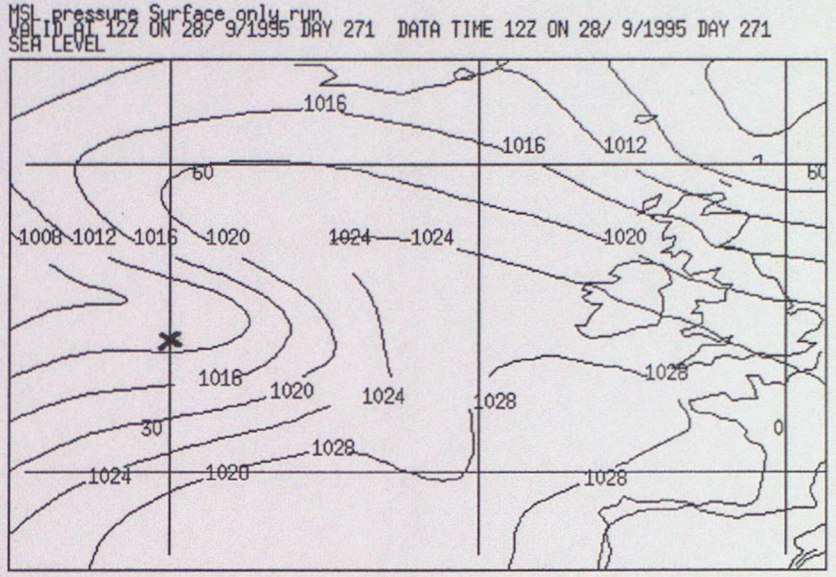


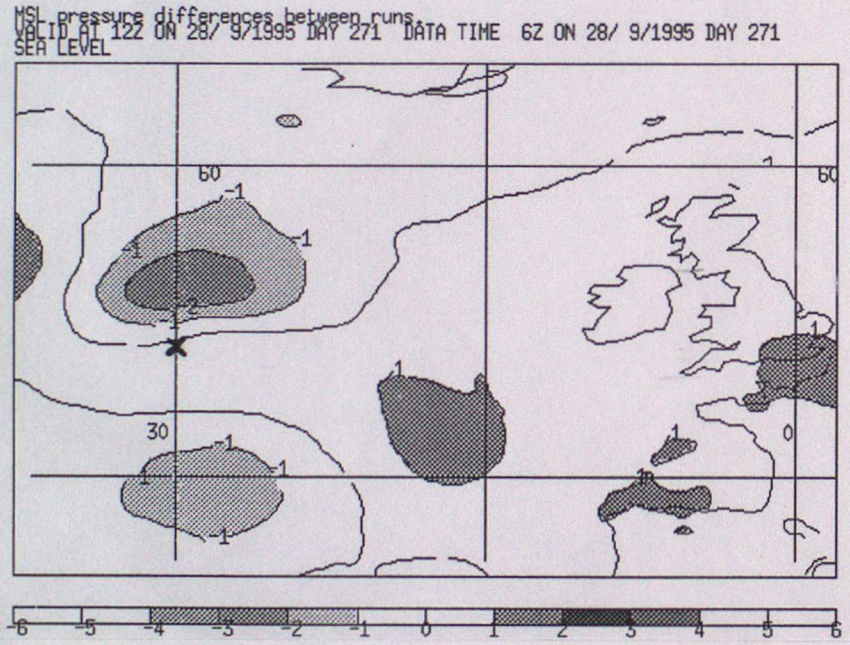
14. 6-hr rain accumulation 29/0600-1200:
NOOBS, AC Winds only and the difference (NOOBS-AC winds only).

Screen dumped by Roger Grant at 11:47 on Fri 10 Nov 1995.

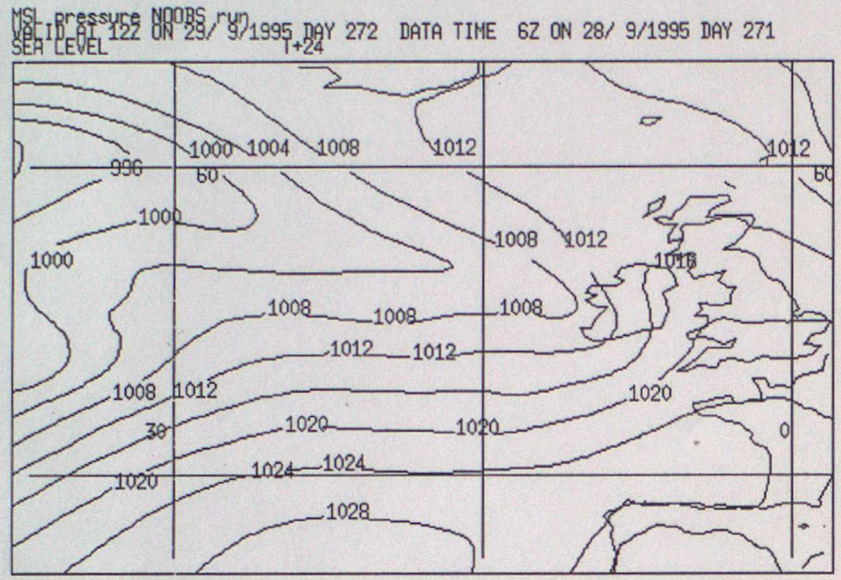
Screen dumped by Roger Grant at 08.58 on Mon 13 Nov 1995.

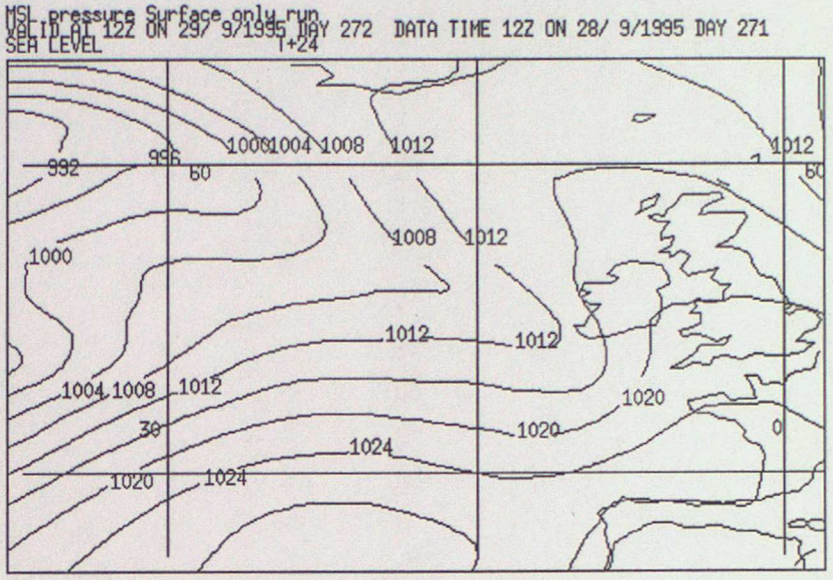


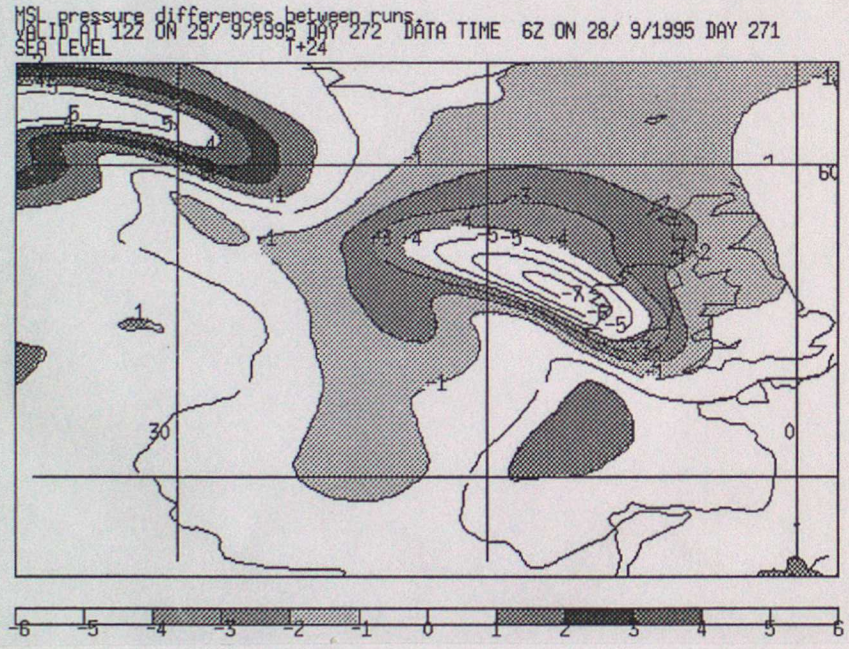




15. MSLP at t+0:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs) only.
X marks the CFO hand-analysed position of Low U.

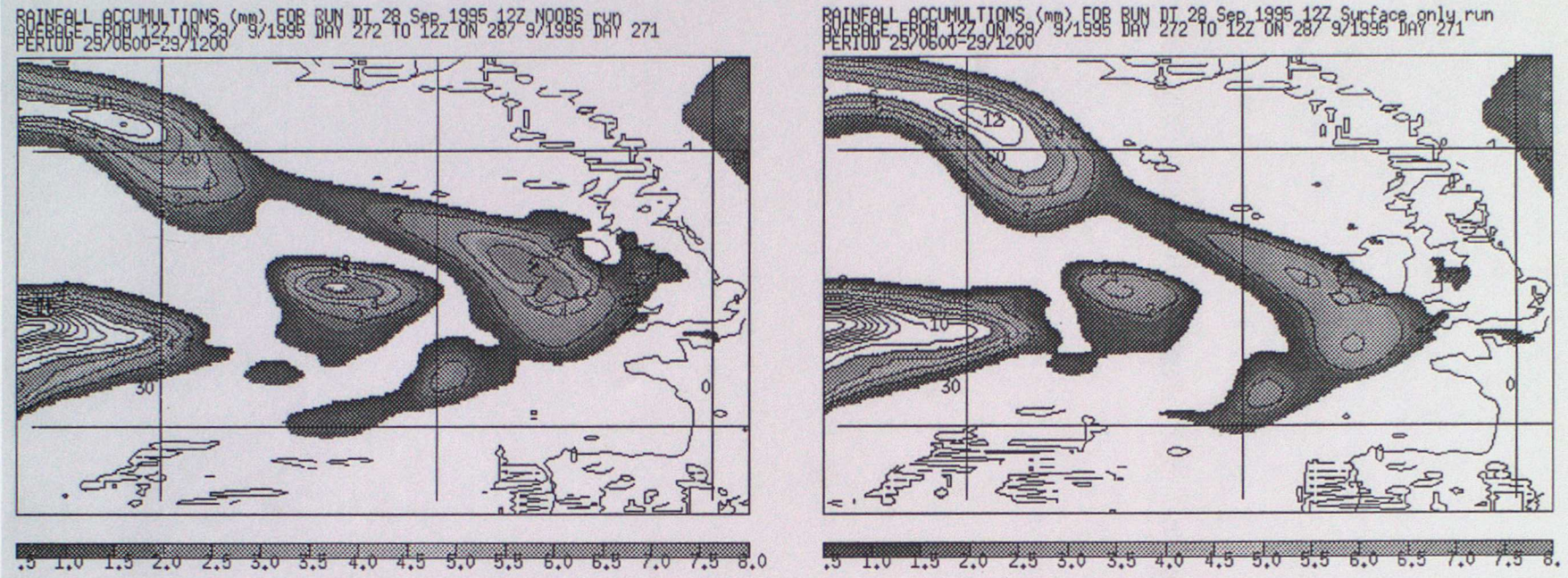






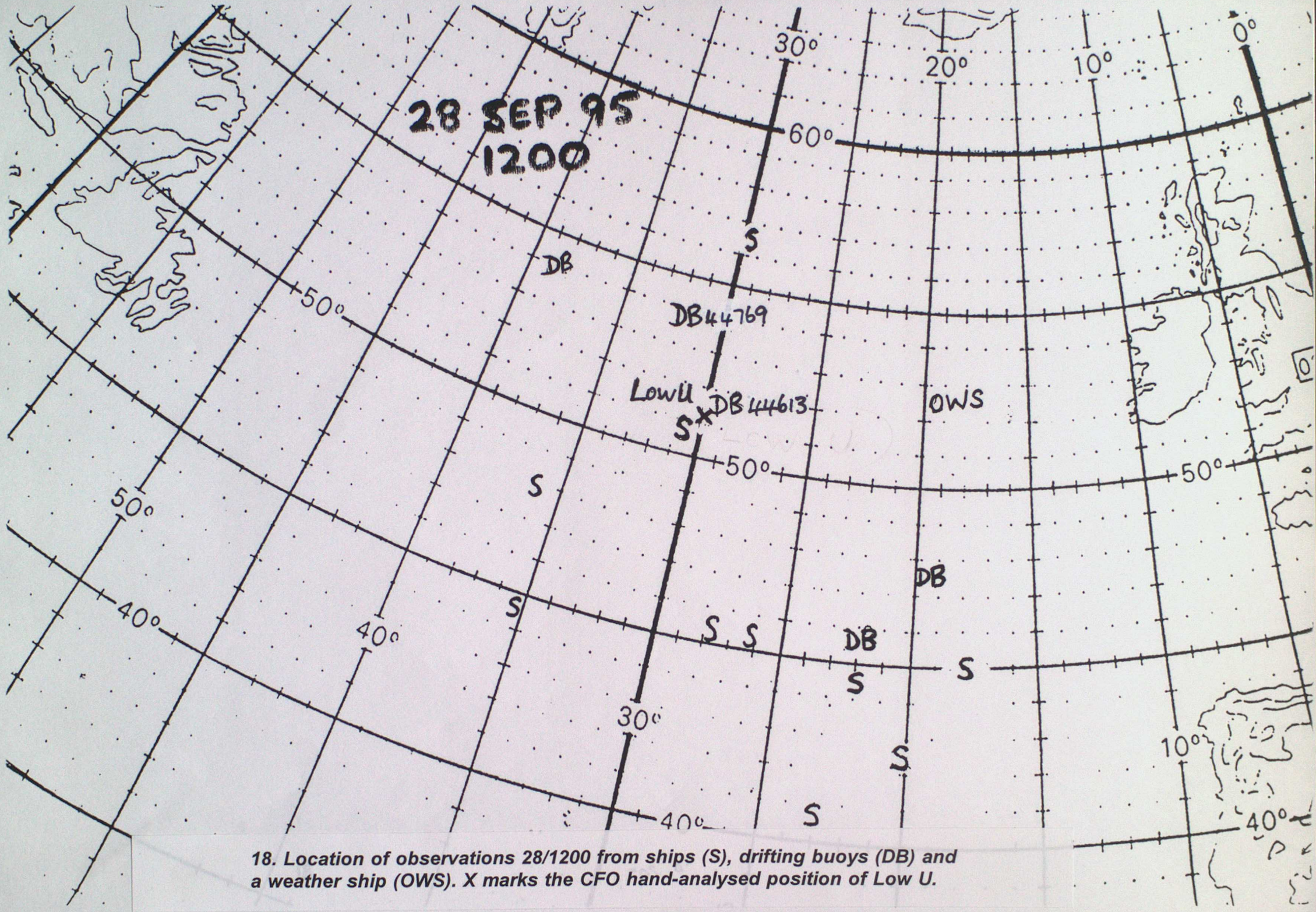
16. MSLP at t+24:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

Screen dumped by Roger Grant at 09:01 on Mon 13 Nov 1995.

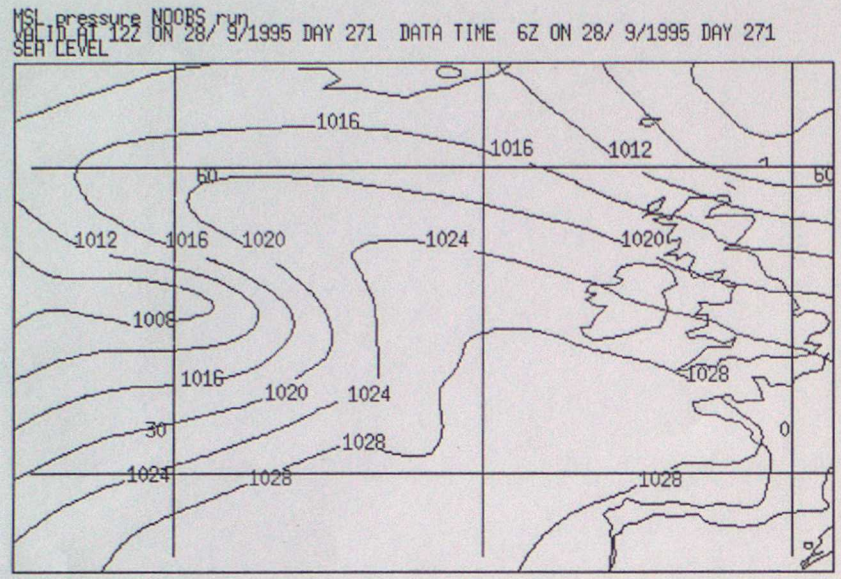


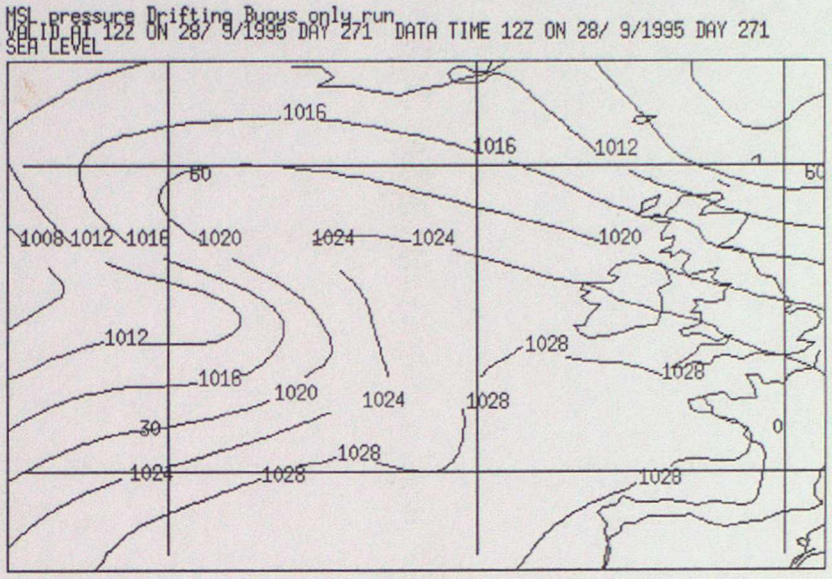
17. 6-hr rain accumulation 29/0600-1200:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

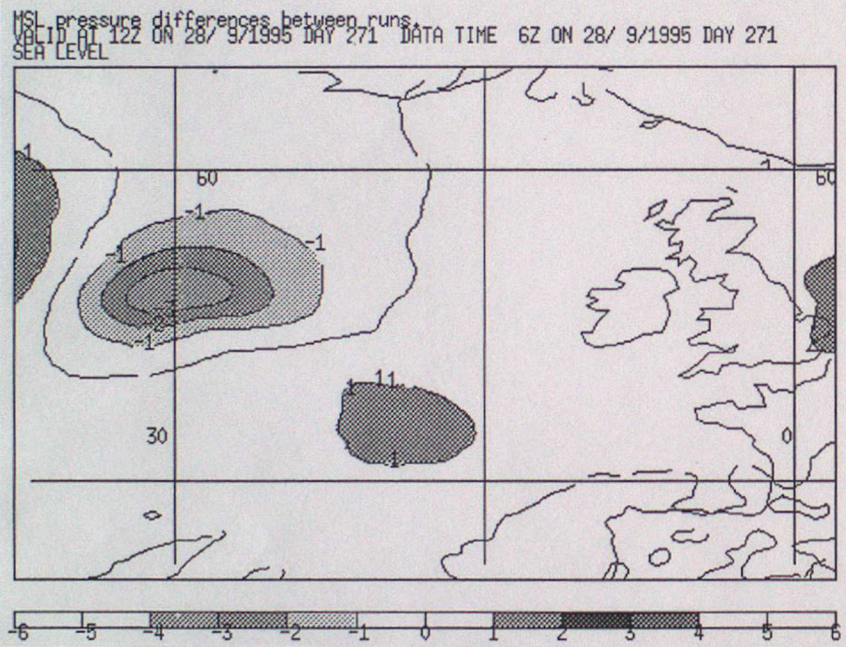
Screen dumped by Roger Grant at 10:19 on Mon 13 Nov 1995.



18. Location of observations 28/1200 from ships (S), drifting buoys (DB) and a weather ship (OWS). X marks the CFO hand-analysed position of Low U.

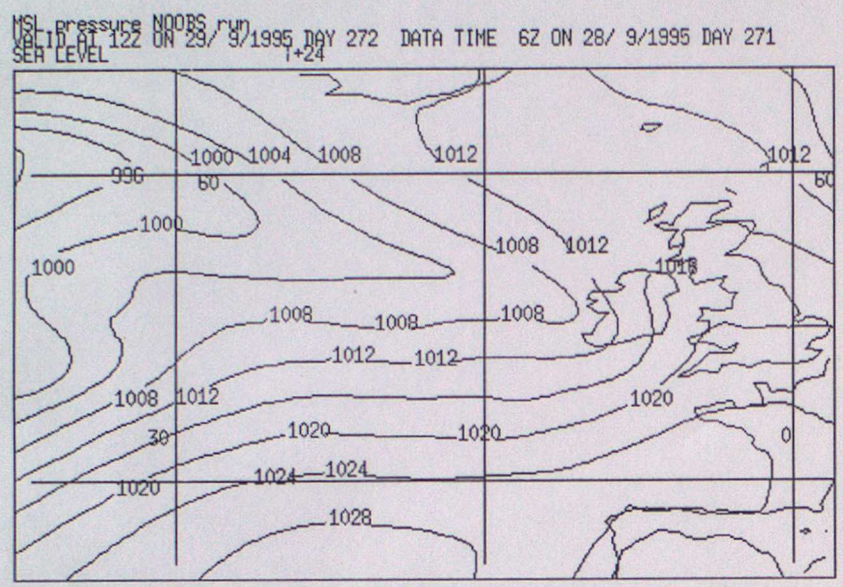


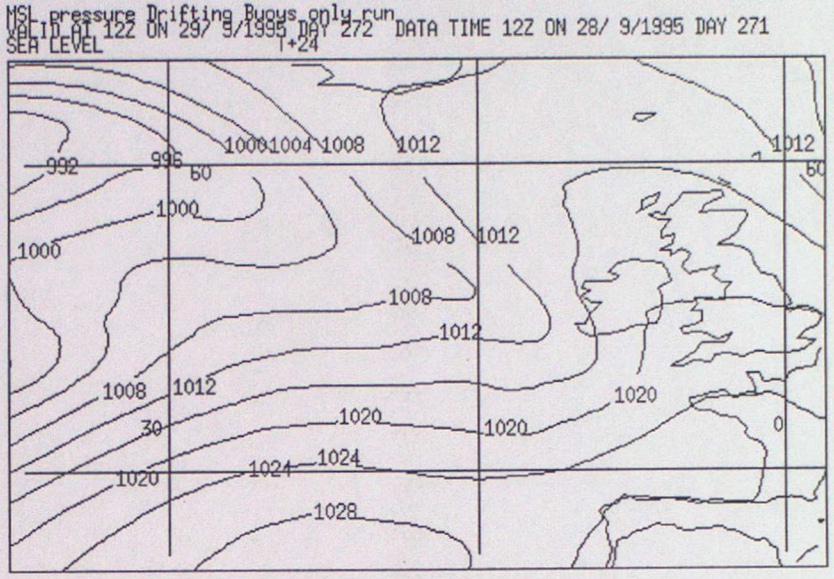


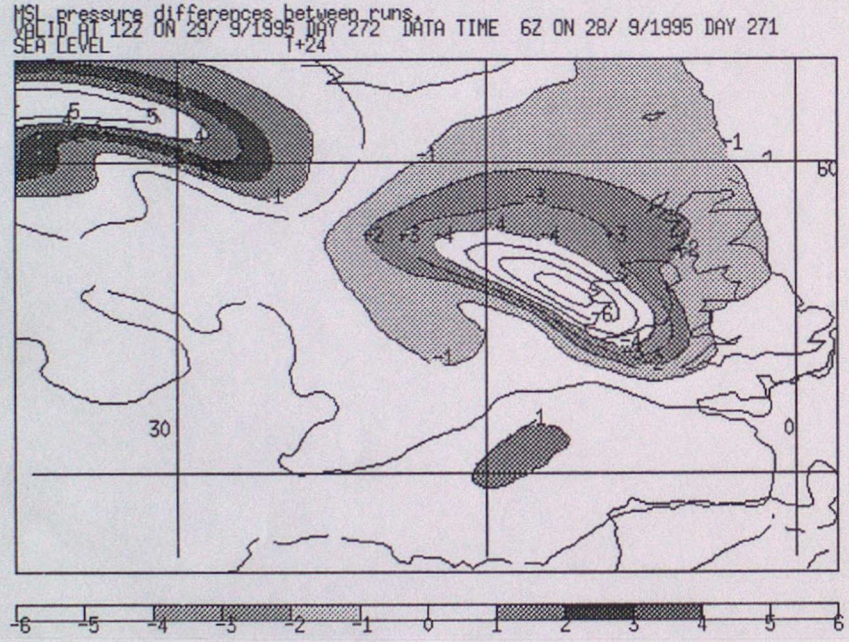


19. MSLP at t+0:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

Screen dumped by Roger Crutt at 14:07 on Fri 05 Jan 1996.

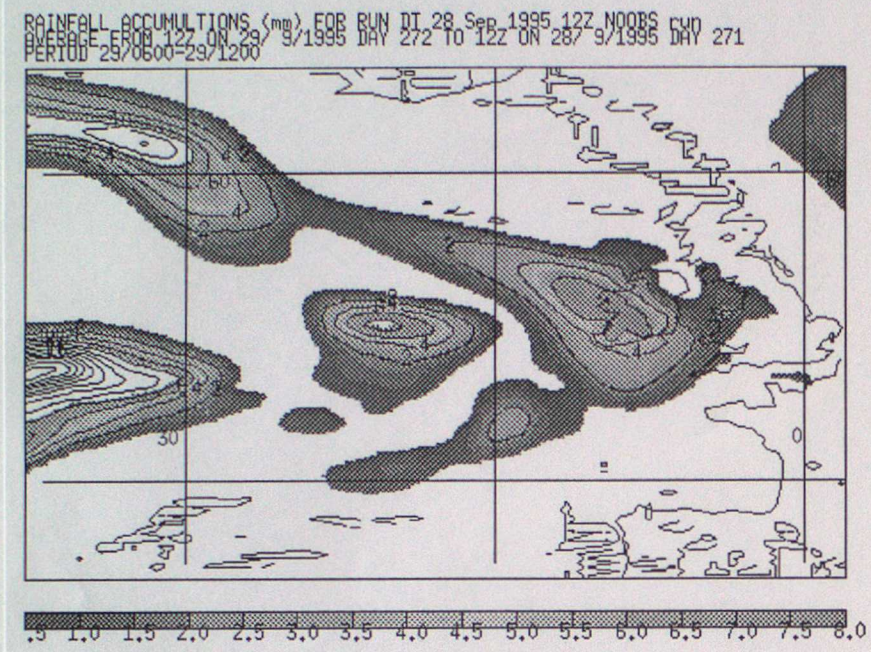


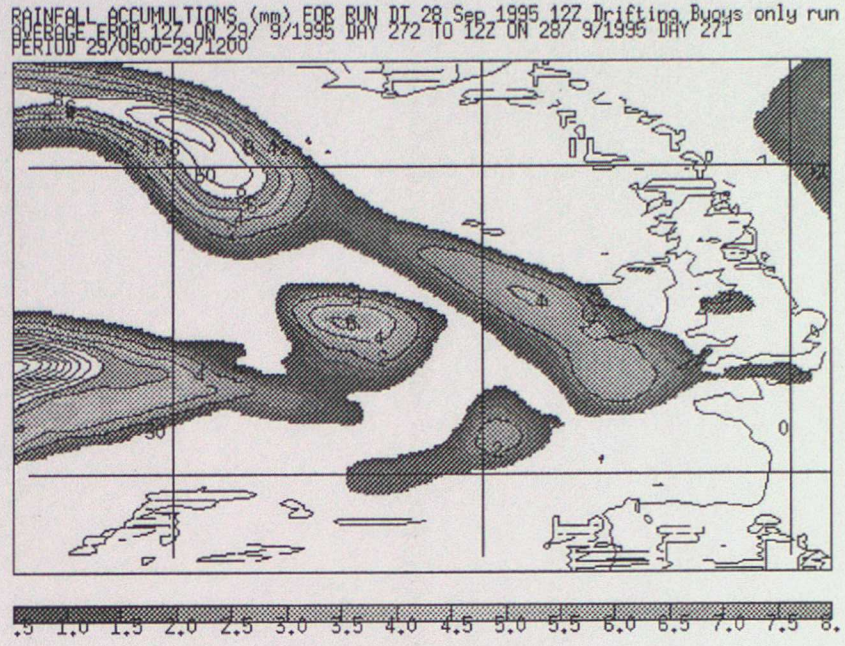


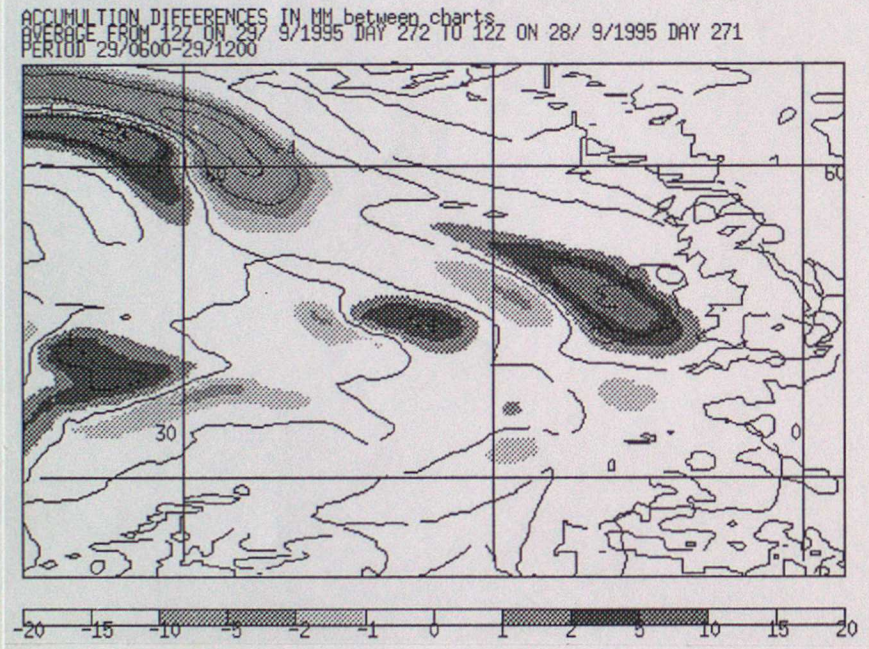


20. MSLP at t+24:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

Screen dumped by Roger Grant at 14:15 on Fri 05 Jan 1996.

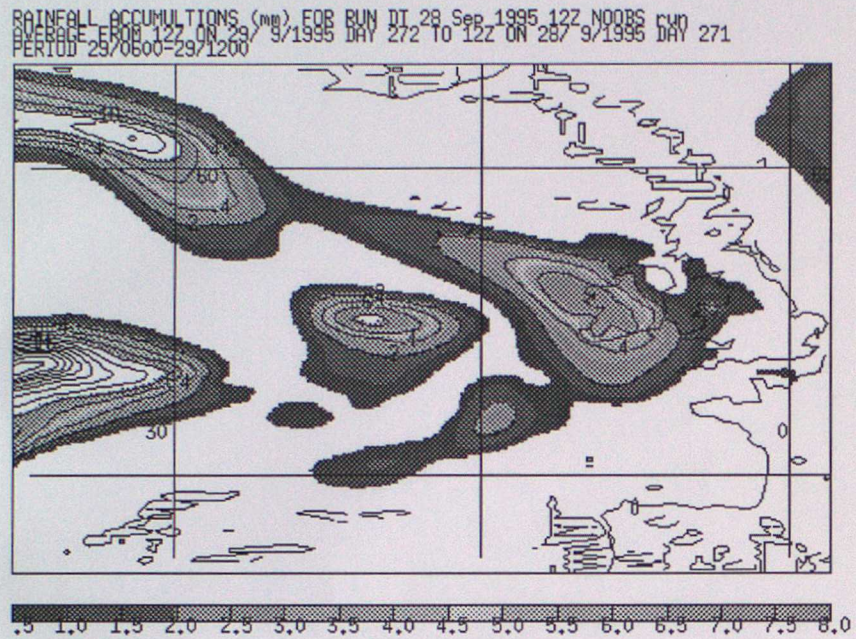


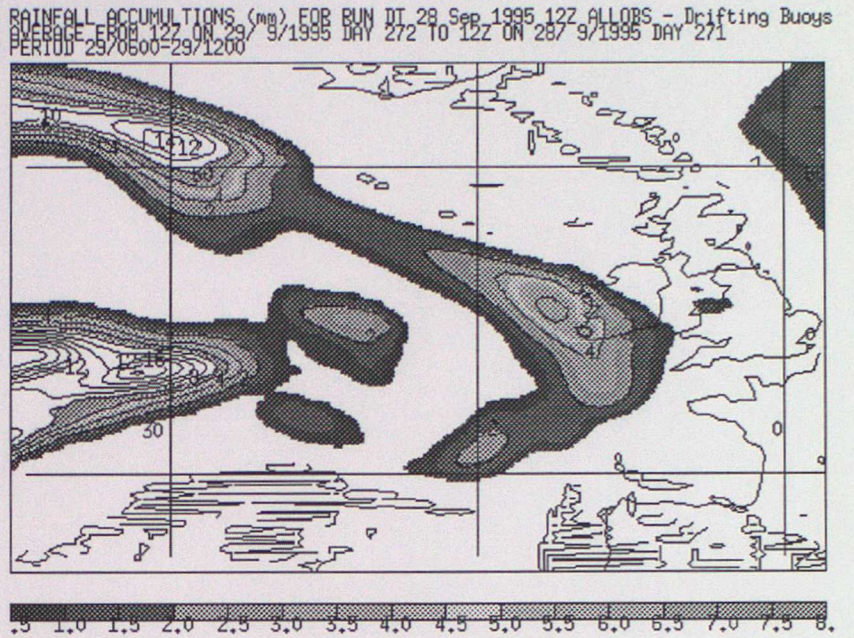


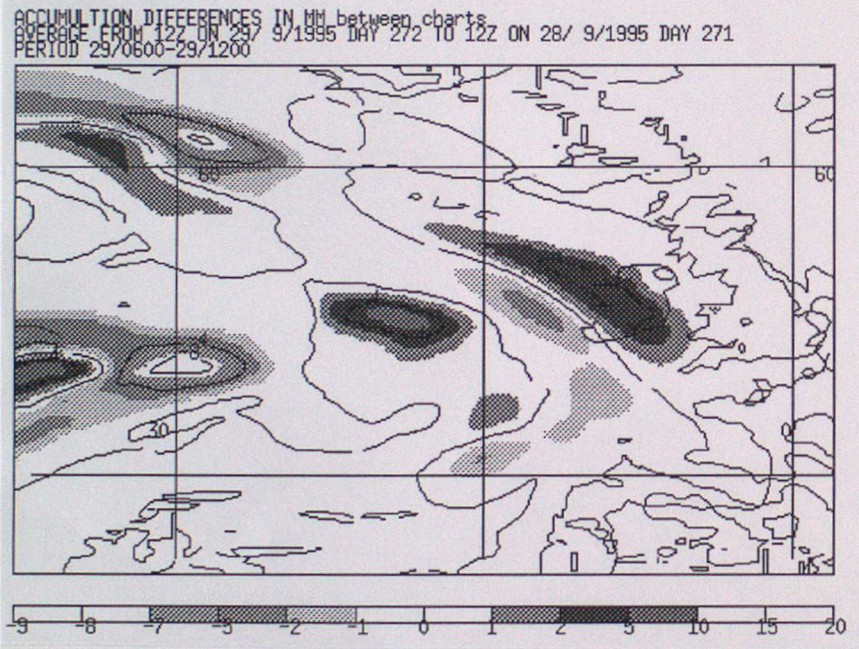


21. 6-hr rain accumulation 29/0600-1200:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

Screen dumped by Roger Grant at 14:06 on Fri 05 Jan 1996

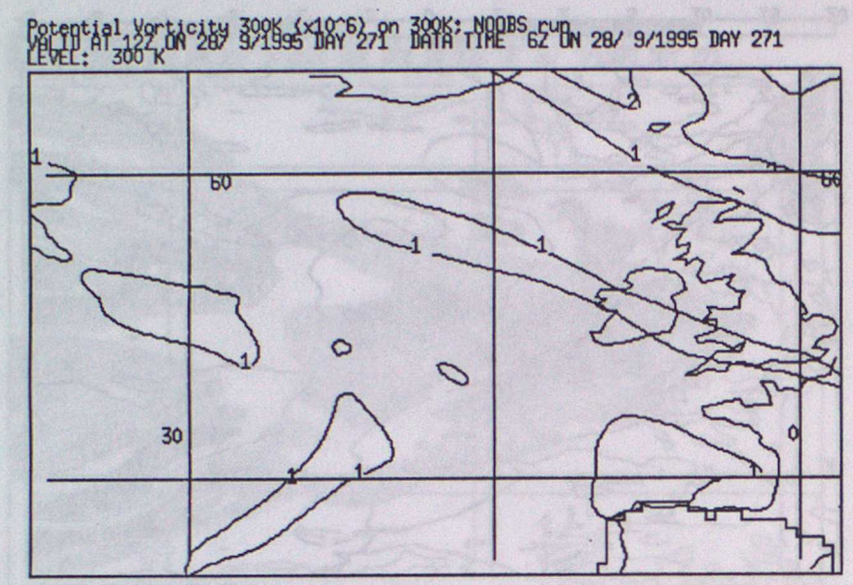


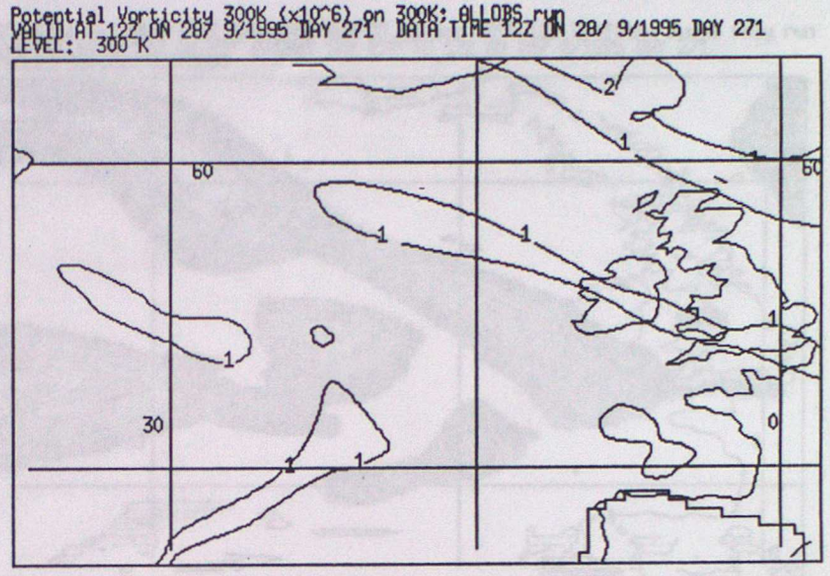


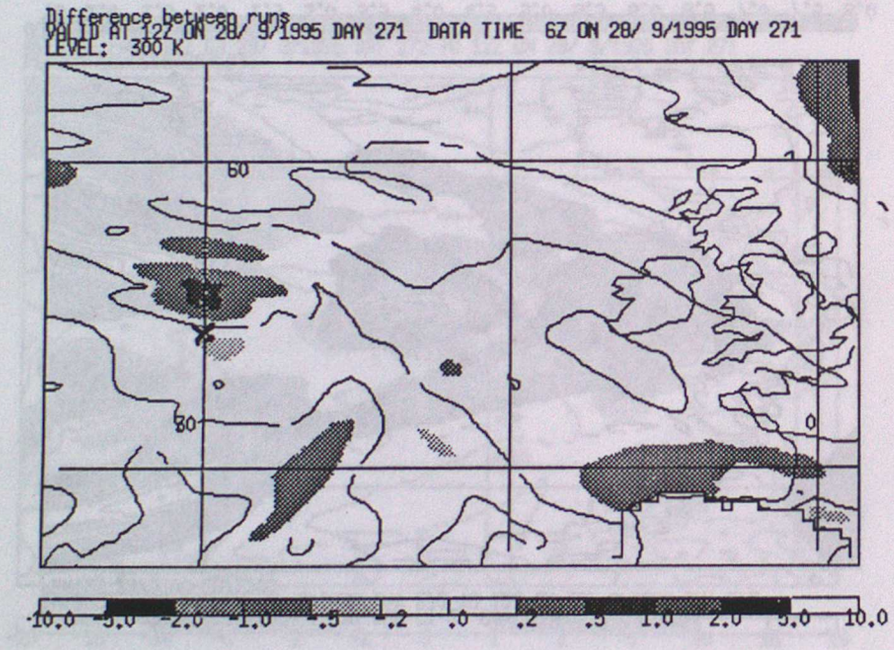


22. 6-hr rain accumulation 29/0600-1200; NOOBS, (ALLOBS - Drifting Buoys) and the difference.

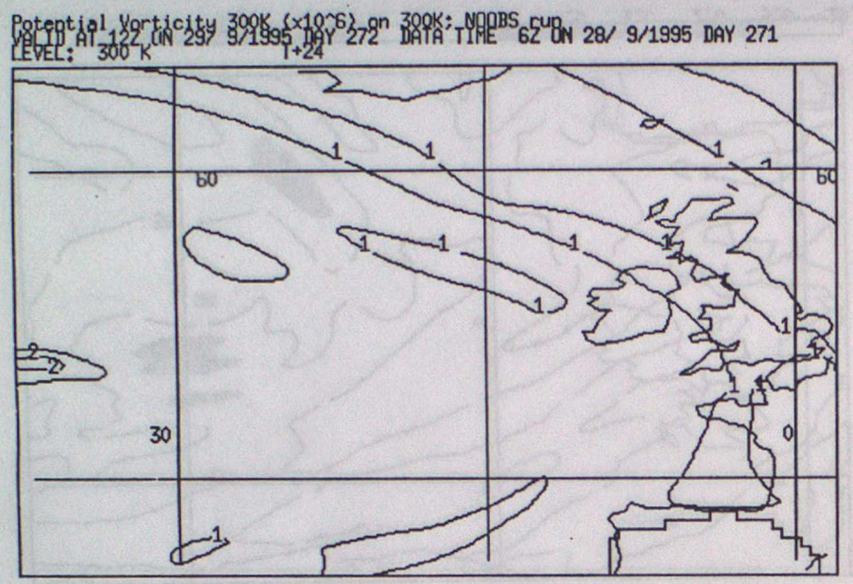
Screen dumped by Roger Grant at 11:53 on Wed 28 Feb 1996.

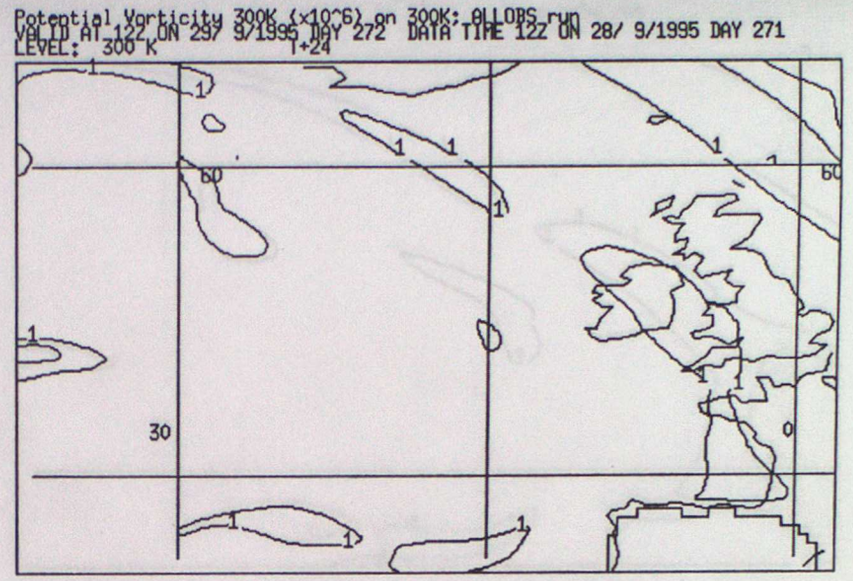


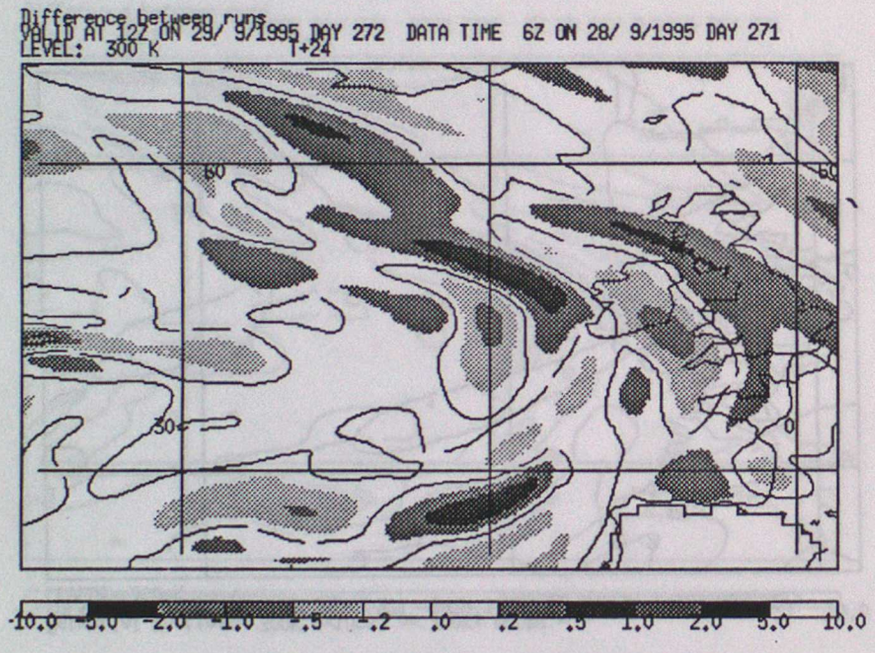




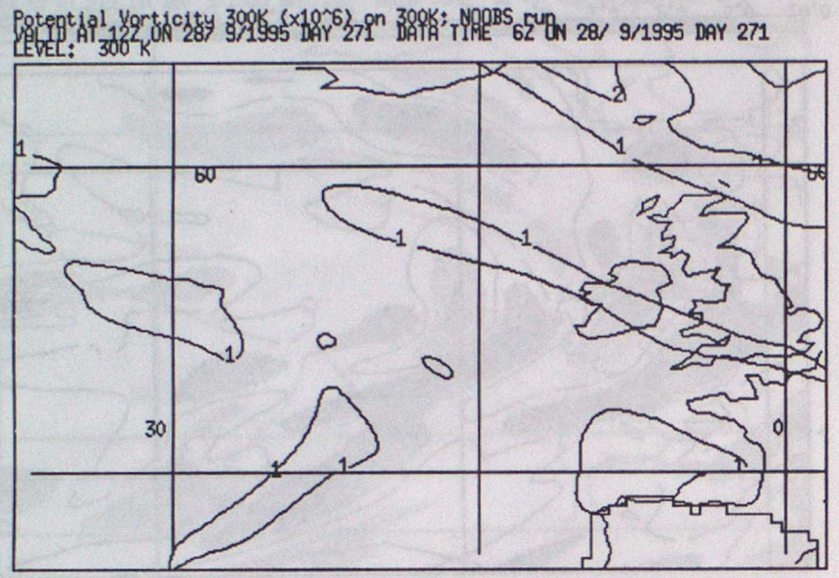
23. PV on 300K surface at t+0:
NOOBS, ALLOBS and the difference (NOOBS-ALLOBS). X marks Low U.

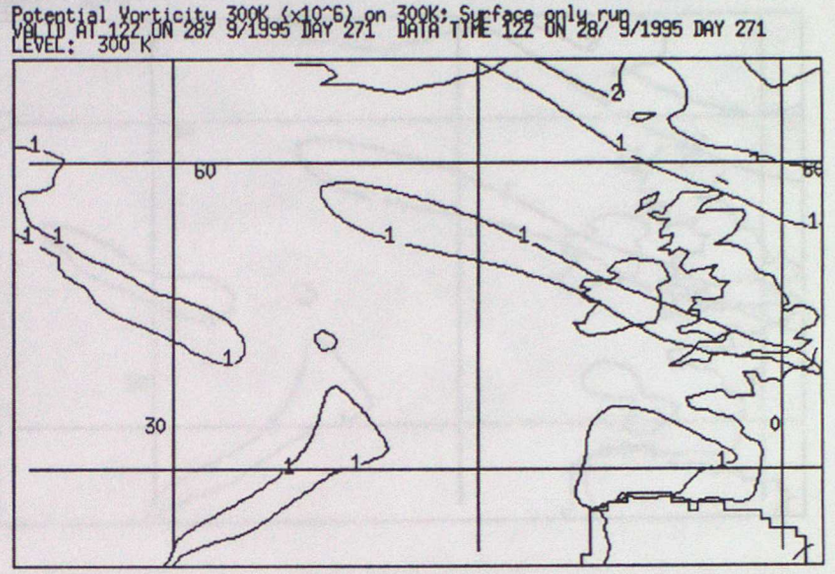


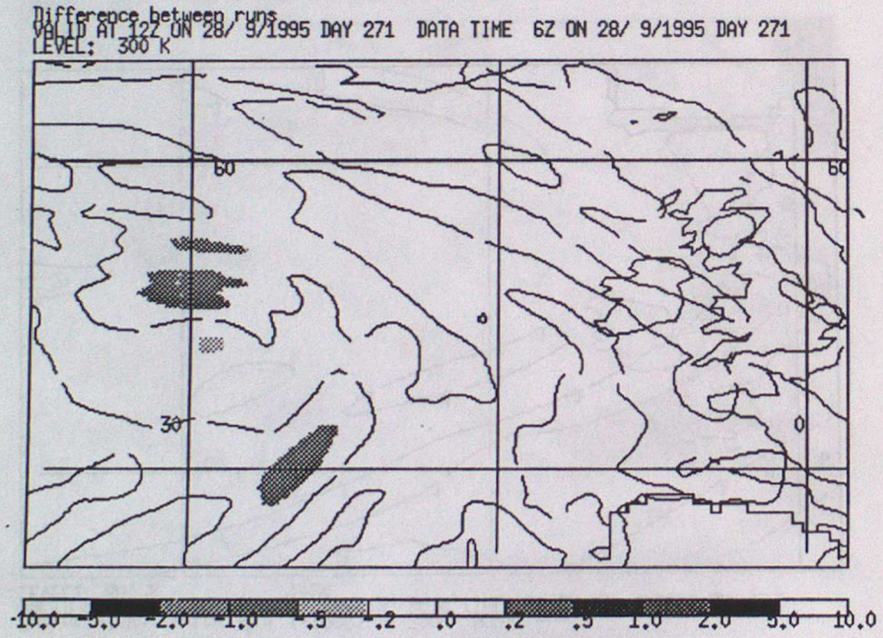




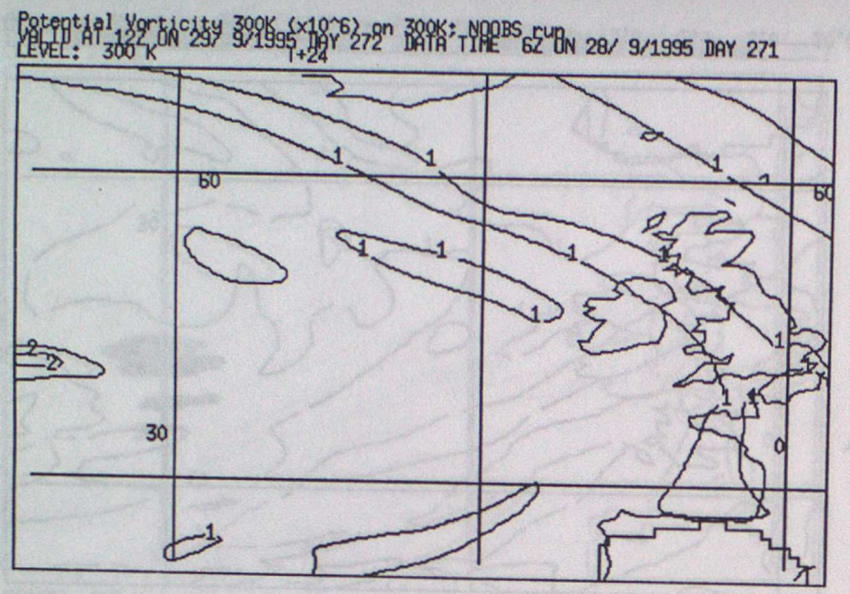
24. PV on 300K surface at t+24:
NOOBS, ALLOBS and the difference (NOOBS-ALLOBS).

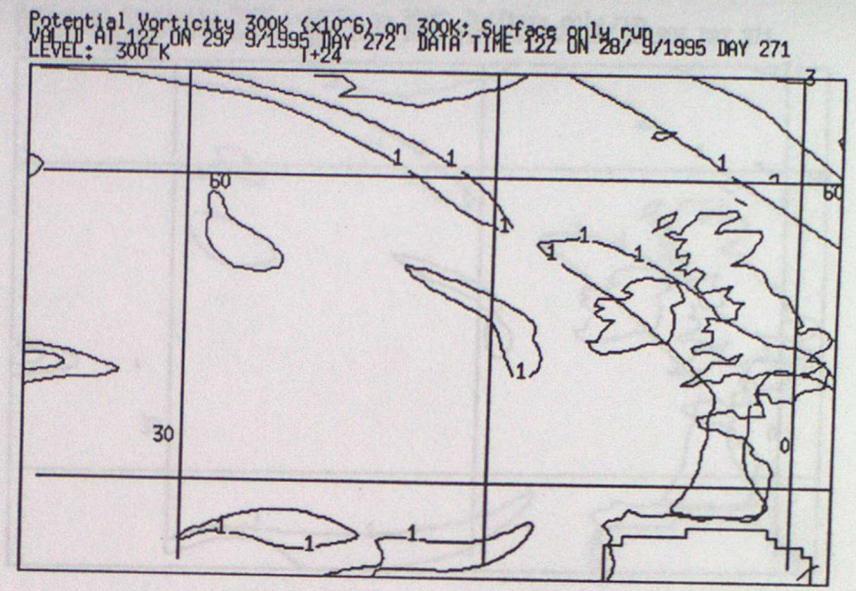


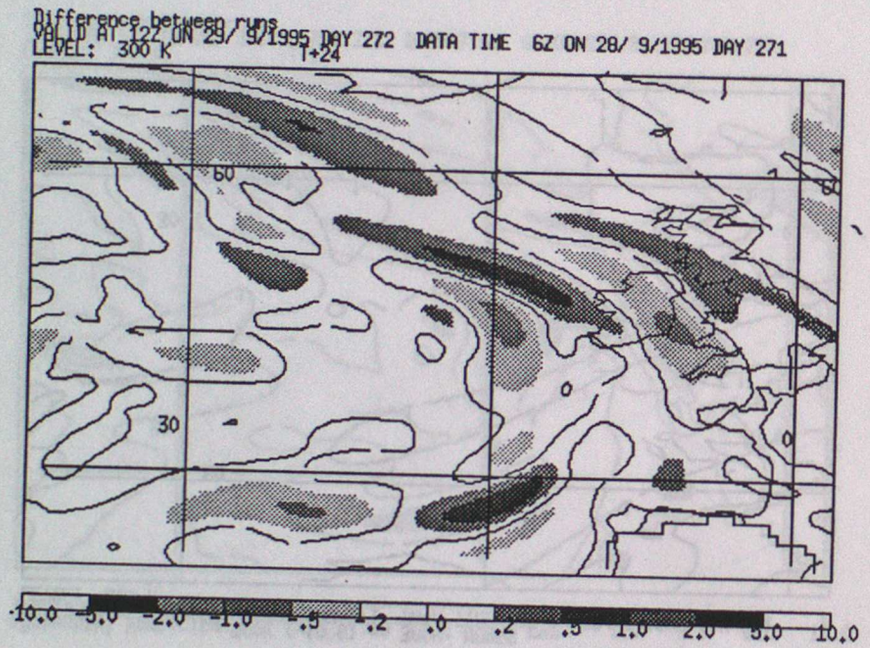




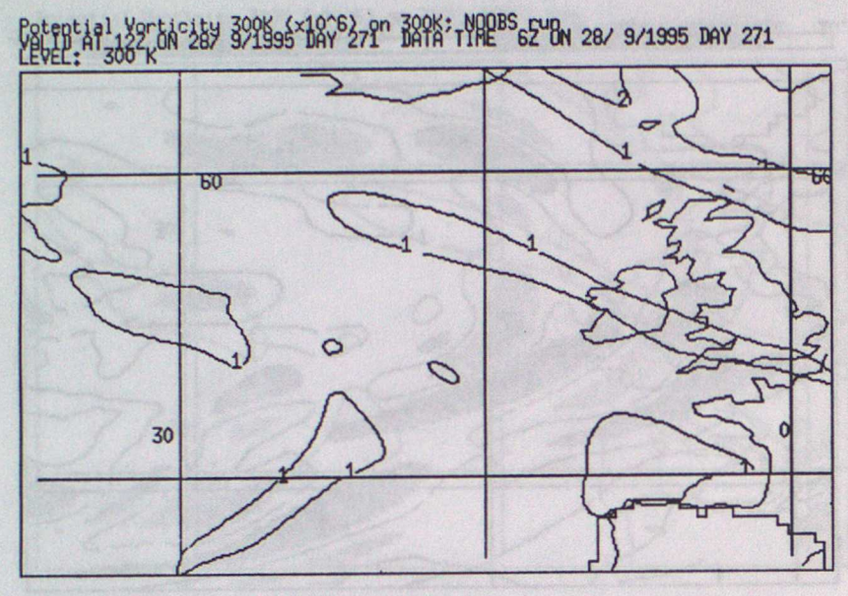
25. PV on 300K surface at t+0:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

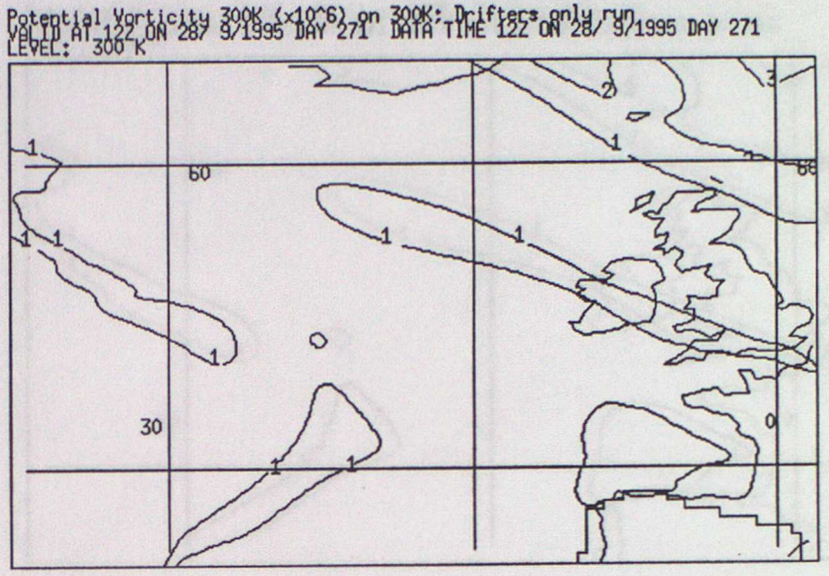


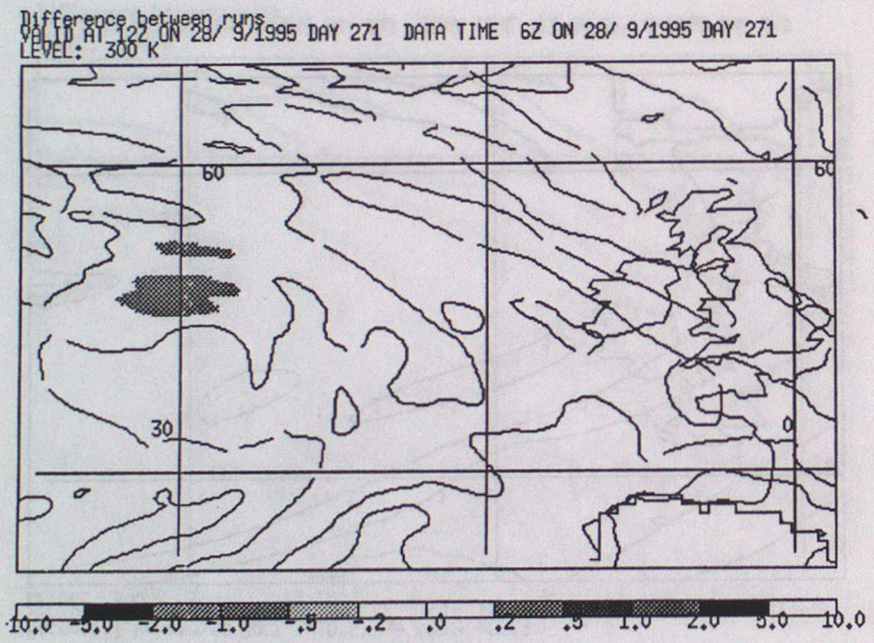




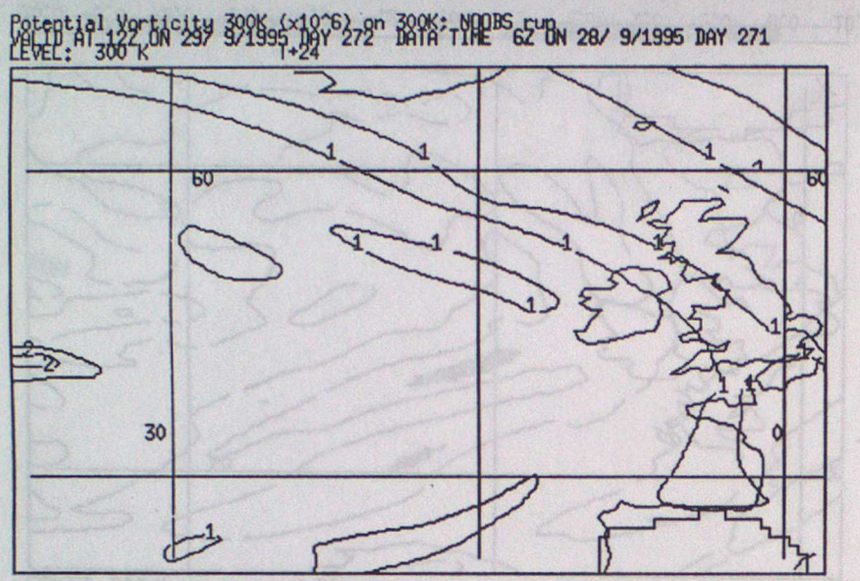
26. PV on 300K surface at t+24:
NOOBS, Surface observations only and the difference (NOOBS-Surface obs only).

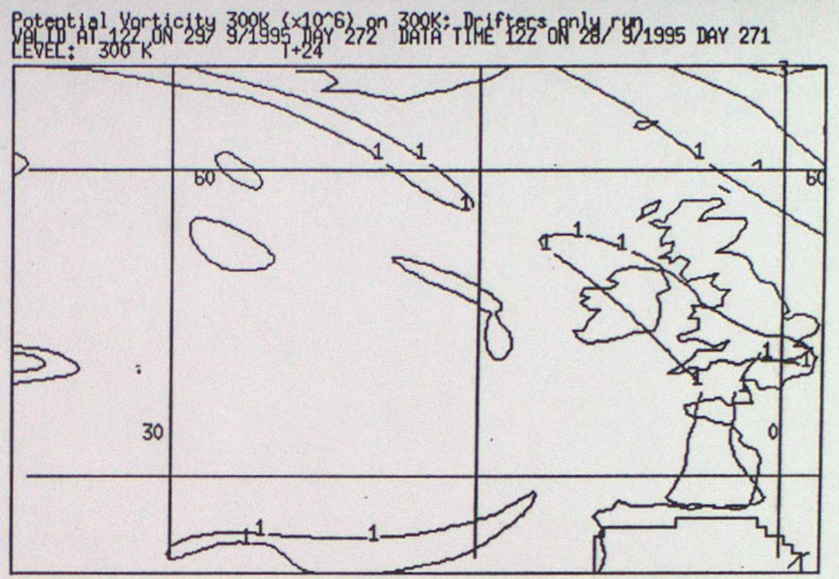


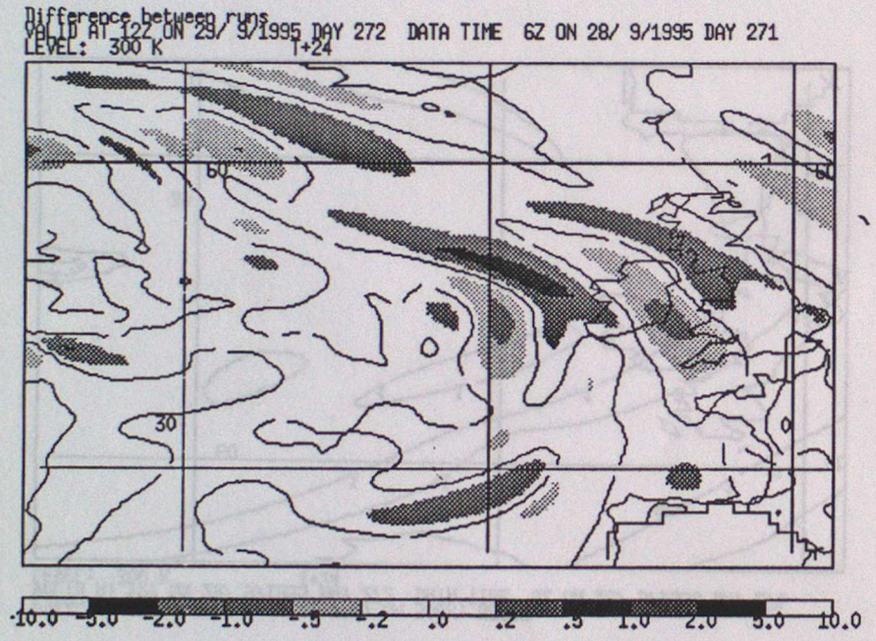




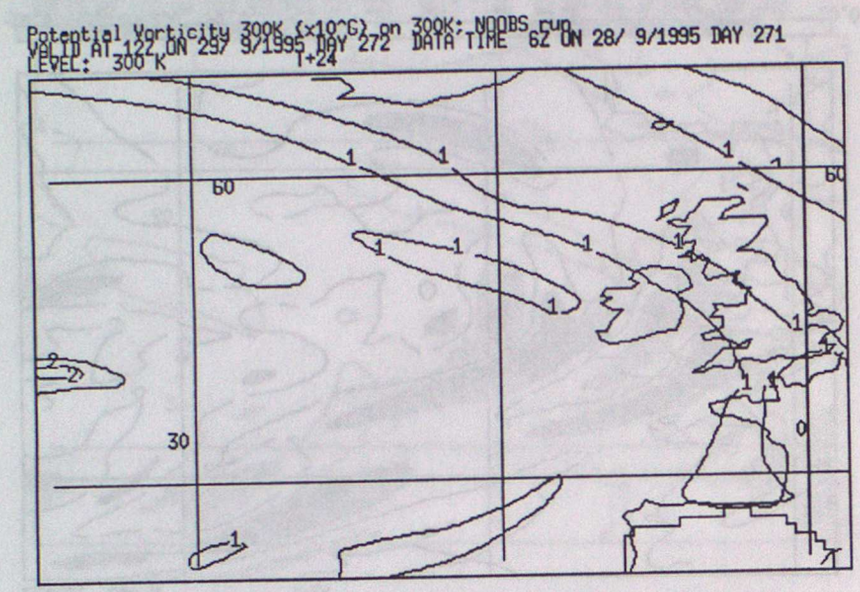
27. PV on 300K surface at t+0:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).

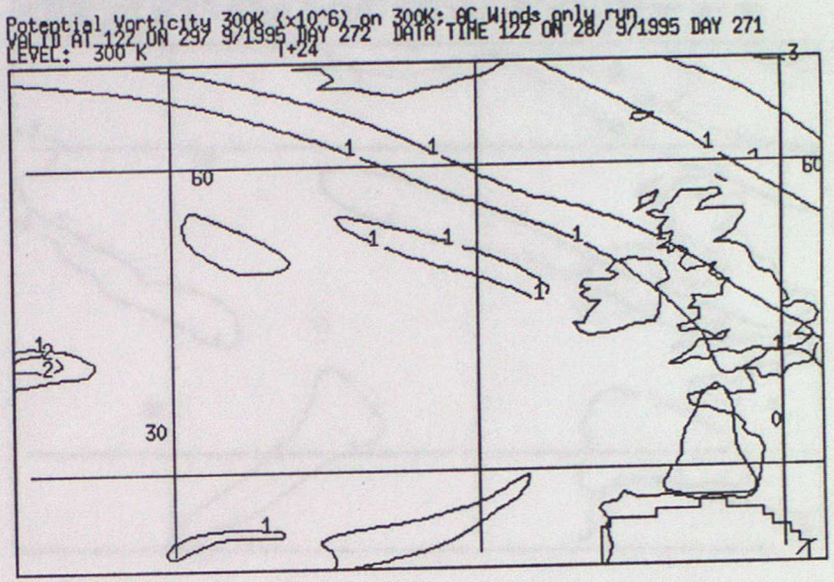


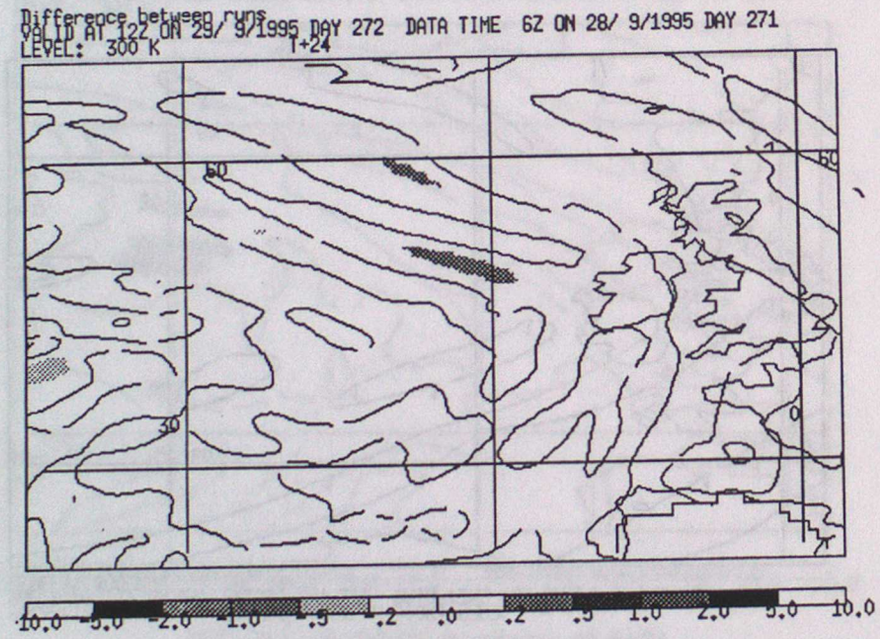




28. PV on 300K surface at t+24:
NOOBS, Drifting Buoys only and the difference (NOOBS- Drifting Buoys only).







29. PV on 300K surface at t+24:
NOOBS, AC Winds only and the difference (NOOBS- AC Winds only).